RESEARCH AND THESIS WRITING

UNDER THE EDITORSHIP OF

ELLWOOD P. CUBBERLEY

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LELAND STANFORD JUNIOR UNIVERSITY

RESEARCH AND THESIS WRITING

A Textbook on the Principles and Techniques of Thesis Construction for the use of Graduate Students in Universities and Colleges

BY

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HOUGHTON MIFFLIN COMPANY

BOSTON · NEW YORK · CHICAGO · DALLAS

ATLANTA · SAN FRANCISCO

The Riverside Press Cambridge

The Riverside Press
CAMBRIDGE · MASSACHUSETTS
PRINTED IN THE U.S.A.

EDITOR'S INTRODUCTION

The very rapid increase in the number of graduate students in our universities, within the past decade or two, has been a marked characteristic of recent university development. This increase has not been confined to any one or even to a few fields of organized knowledge, but has been distributed over the whole range of university instruction. The number of master's and doctor's degrees granted in the United States has increased rapidly within recent years, and the work of preparing the candidates for these higher degrees has likewise increased markedly in amount and in importance as a phase of university work.

With this increase in the number of candidates for the higher degrees, a change in the methods of preparing them for candidacy has become necessary. If the time they are to devote to graduate study is to be most advantageously spent, they need training, early in their graduate years, in finding and delimiting their problems, in scientific methods in research work, in library and thesis technique, in the proper organization of their work and of their thinking, and in standards for judging their progress and the completed product. To impart this knowledge and training, where many graduate students have to be handled, calls for the organization of courses introductory to thesis work and in the principles of research.

As such training courses have begun to be organized in our universities, there have appeared, largely within the past

three or four years, several guides to thesis construction and to research work. Most of these guides deal mainly with thesis construction and research work in the field of education. In part this has been due to the insistent demand for organized procedures to enable instructors in this subject to handle the rapidly increasing number of graduate students. There is little reason, however, for giving education special attention, since students in other departments in a university are equally in need of direction. Still more, the principles involved in research work in education are not especially different from those involved in research in pure and applied science, law, history, economics, or other university fields of knowledge. On the contrary, there are sound reasons why students in education should become familiar with the general principles of scientific method and the research technique of workers in other fields, as well as with the essentials of thesis technique in their more limited field.

Believing in the importance of this more general introductory procedure, the author of the present volume has prepared a textbook that can be used, in a course in the Principles of Research, by a professor in any department of a university. He holds that the fundamental principles of scientific method involved in research in any field of human knowledge are not essentially different in character, and that the techniques involved in thesis writing are practically the same for all fields of university study. Consequently, he has presented a textbook that is general in character and in its appeal, rather than specialized and limited largely to a single department of graduate work. This is one of the special merits of the present volume. At the same time the text is

of such a character that it may be used by a professor and students interested only in educational, or historical, or biological, or economic research. The text also could be used equally well in a course dealing with the needs of a mixed group of graduate students training for research work in a wide variety of university subjects.

With the rapidly growing demand for organized procedures and directed training of groups of graduate students proposing to engage in research undertakings as part of the requirements for the higher university degrees, it is believed that this more general type of textbook will meet the needs of a wide variety of teachers and students in the different fields of university study. The questions and the problems attached to the different chapters are of such a nature that it will be easy for any instructor using the book to adapt it more fully to the particular requirements of his special line of study.

ELLWOOD P. CUBBERLEY

PREFACE

This book has been written for graduate students in colleges and universities who are engaged in the preparation of theses, and for teachers directing research work in seminar and laboratory. It deals with the fundamentals of research and thesis making, with but minor attention to ways and means. The purpose has been to set down some of the simple but basic items of information needed by typical beginners. The two introductory chapters take up the meaning of research and the thesis, and the nature, sources, and criteria of problems. These are followed by two chapters which set forth the underlying principles of the scientific method. The three chapters which follow treat, in some detail, the methods of normative, experimental, and historical research. These in turn are succeeded by three chapters containing suggestions as to the techniques for applying minor methods of investigation, using the library, and writing the thesis report. The final chapter deals with the evaluation of results.

The book may be used to advantage by an instructor of a course of one to three units in Principles of Research and Thesis Making. The materials and organization have been evolved largely out of the author's experience in teaching such a course, and, to a lesser degree, from his experience in guiding the individual efforts of students engaged in the preparation of master's and doctor's theses. Special attention is called to the questions designed to stimulate discus-

sion, and to the problem situations, placed at the end of each chapter. One problem is sufficient for a week's work; the extra problems provide variety and give a margin of choice. The author uses the problem method almost wholly in teaching this course.

The conviction of the writer is that scientific method, as common to all fields of knowledge, should be recognized, not only by students in the professions of medicine, law, engineering, and education, but by students in other departments of the university — scientific, historical, economical, literary — as well. All graduate students need to know something of normative, experimental, and historical methods. They need this knowledge to enable them to choose their own problems more wisely, to solve them more successfully, and to guide the research work of others when they in turn become teachers. They need to appreciate the unity of science. The experimentalist should have an interest in, and at least an elementary understanding of, the science of values and the science of history. Likewise, students in normative and historical sciences should know something of the experimental process. All equally are in need of knowing how to use the library, how to take care of the writing mechanics, and how to judge the final results.

Once the fundamental principles of scientific method are mastered, the difficulties in the way of the acquisition of techniques are lessened. The task of preparing a thesis then may be pursued with understanding from the beginning. The fundamentals of scientific method are not many, nor are they complex, yet students may take courses for years, and succeed in them, without obtaining more than a dim

understanding of what science is and what science means. If our students are really to become working scientists, and not mere craftsmen and course-tasters, they must acquire a knowledge of the basis of the scientific process.

The reader of this volume will observe that many references have been made to the work of great scientists. This has been done consciously, because of a belief that the study of superior performance will prove helpful to the beginner in forming ideals and attitudes, and in acquiring skills. Certain topics, particularly those dealing with techniques, have been given adequate but rather minor attention for another reason: namely, they have been well presented in the excellent books on research that have appeared within the last two or three years — for example, the books by Crawford, Good, and Schluter. Although the writer undoubtedly has duplicated some of the materials found in these texts, he has tried to supplement, rather than to repeat, what has already been done.

Very little has been said in this work about the method of reflective thinking, as such, in the scientific process. There is no need for concealing the reason for this apparent neglect. The writer is not laboring under the impression that reflective thinking is unimportant or its practice unnecessary. He feels, however, unequal to the task of explaining its process, and has grave doubts whether there are available at this time any directions of known reliability. Such suggestions as might be formulated, or that have been formulated, appear to have in them a large element of opinion and speculation. The writer fails to see any break at all between what is real research and what is real reflection.

An examination of the methods of the great scientists indicates that they advanced toward their objectives without any consciousness that they were at one instant collecting data, at another instant making inductions, and at still another instant passing again to the particular. Unity in the scientific process, unity in the applications of science, and unity of all knowledge are concepts in which the writer has full faith. Likewise, he is not able to discern degrees of high or low in truth; history, natural science, and normative science are to him on the same plane. They are truth tested and put in order.

There is no desire, however, to start a controversy over this point, or any other. The thesis requirement to-day is universal for those who seek higher degrees, and students desiring them must proceed to prepare theses with what intelligence, honesty, expedition, and skill they may possess. In the volume here presented an attempt has been made to be helpful to beginners; the elementary character of the ideas is acknowledged. No claim to originality nor to complete success in realizing the objective which has just been stated is made. The sciences have been classified as normative, experimental, and historical; the kinship of all sciences has been shown as clearly as possible; the foundational principles of the scientific method have been introduced; advice on the elements of thesis mechanics has been offered, and a few suggestions for evaluating the final results have been given.

The references at the end of each chapter have been selected from a large body of material. The main consideration has been to list references usually available, helpful, on

the level of the beginner in research, and in harmony with the aim of the text. There are certainly many other useful books and articles which students could well afford to read, but, within a book of so limited a scope as this, they had to be omitted. A frank confession may as well be made that the writer believes it is undesirable to offer a large and an extensive list of references in a textbook. A limited number of what the librarian calls "best books" is more conducive to prompt and intelligent use than is a large unselected mass of materials, with which the students have neither the time, the ability, nor the inclination to cope. Where a choice of books has been permissible, preference has been given to scientists, rather than to logicians and philosophers. If this is a fault, it is one before which the writer stands unabashed.

Thanks are especially due to William G. Carr, Assistant Director of Research, National Education Association, Washington, D.C., for materials, advice, and criticism. Miss Florence Craig, of the Stanford University Library, was most obliging in supplying information relative to the use of the library. John R. Nichols and Charles H. Bursch, graduate students at Stanford, read a considerable portion of the manuscript, and made many suggestions which the writer accepted and now gratefully acknowledges. My colleagues, Professors Harold R. Benjamin, Truman L. Kelley, and Ellwood P. Cubberley, have been generous in materials, suggestions, and criticisms. To all, I express my appreciation.

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RESEARCH AND THESIS WRITING

CHAPTER I

THE ACADEMIC THESIS AND RESEARCH

The thesis requirement. The preparation of a thesis is to-day a universal requirement for a higher degree. Typical regulations for the Master of Arts degree specify that "the student must present a satisfactory thesis"; "the department work will include a thesis based upon laboratory work"; and "the ability to do independent research as evidenced by an acceptable thesis is required." For the Doctor of Philosophy degree universities insist upon a thesis "covering a limited range," which further must be "a contribution to knowledge and the result of independent work." The common terms found in the different requirements are "research" and "independent work"; the more advanced degree specifies also that the thesis must be "a contribution to knowledge."

Such requirements are consistent with the theory of higher education. As universities are now organized, three fairly definite stages in the educational process are recognized. *The first of these stages* may be termed *period of the mastery of knowledge.* During this period the student

relies chiefly upon available sources of information (books and teachers), and makes little or no attempt to add to the store of truth or to apply in a new way the knowledge which already exists. He is not forbidden to make discoveries, but his attention is directed chiefly to the acquisition of tools and the assimilation of facts and principles. The first stage culminates in the bachelor of arts degree, signifying mastery of one or more of the organized fields of knowledge, such as biology, chemistry, or psychology.

The second stage signifies *mastery of the techniques by which knowledge is tested and additions are made to the sum total.* Mastery of techniques implies that the student is a person of initiative and intelligence. He commences to work independently, and especially he acquaints himself with the problems and methods of scientific investigation. He learns by experience how to perform a piece of critical and constructive research. Such experience gives valuable training, but it is not necessarily to be defined as research in the sense of exploration of a new territory. One writer has well described it as "observant travel through a familiar country."[1] The master of arts degree is given at the close of this stage.

While the thesis is almost universally required for the master's degree, it may, in some institutions, be based upon a study of secondary materials rather than upon research. Grier[2] states that of 63 institutions studied, 33 definitely indicate that research is required for the master's thesis in science; two insist upon it in certain departments only, while

[1] F. S. Boas. "Some Aspects of Research," p. 98.

[2] N. M. Grier. "The Master's Degree and Scientific Research," p 570.

nine have no preference between research and other types of material submitted in thesis form. The remainder do not believe that research is necessary for the M.A. degree and do not insist upon it. Of 36 of the larger universities, 29 require research as the basis for the M.A. thesis. The tendency is in accord with the discussion in the preceding paragraph: to require evidence of the ability to do research work as a condition of obtaining the master's degree.

The third stage is designated as *the period of discovery or research.* Achievement is crowned with the award of the doctor's degree. To be eligible for this degree the student is required to carry on an investigation of a subject or problem not previously studied. His results must be new facts and principles; occasionally new techniques are presumed to satisfy the requirements. Such research is, in the words of Hill, "penetration to the frontiers of knowledge — and going beyond."[3] The student discovers new facts, generalizes from them, and combines the whole process and product into a formal report called a thesis. He is given the title of doctor, and presumably is entitled to join the fraternity of research specialists and teachers.

The foregoing enumeration of stages of academic progress and achievement represents minimum standards, rather than rigid requirements. The undergraduate is not prohibited from exercising initiative, originality, and independence in investigation. The thesis submitted by the candidate for the master's degree may represent a contribution to knowledge. There is no general conspiracy in

[3] D. S. Hill. "Application of Research in Relating Industry and Education," p. 10.

universities to throttle genius. Instead, honors courses, the independent-study plan, seminars, and laboratory periods have been designed to give students opportunity to demonstrate special ability. The thesis is another means by which students who can do research well may gain experience and recognition.[4]

Origin of the thesis requirement. The character of the thesis requirement may best be seen by considering its origin. Universities, in their genesis, were similar in their organization to the corporations of workingmen and the commercial and trade leagues with which they were contemporaneous. The university was, after the guild model, an association for taking apprentices into the arts, developing them into journeymen, and at length admitting them into the teaching craft as masters. The essential outcome of the instruction given the student was skill in disputation.

Therefore, after the prospective master had passed his preliminary tests and given instruction under the supervision of a certificated teacher, he was permitted to present himself for examination for admission to the highest rank. The examination took the form of a disputation upon some proposition which the student offered as his "thesis," with the applicant the contender against all comers. A twelfth-century scholar defended the thesis, "Human faith should be based upon reason." This was his masterpiece, analo-

[4] R. D. Carmichael, in "What is Graduate Study?" declares that all graduate study which properly deserves the name involves research. "One acquires the detailed and specific knowledge needed for research, one develops the spirit of inquiry and consecration to the task of extending the bounds of knowledge, and one is inducted into the actual labor of discovery" (p. 739).

gous to the piece of jewelry, furniture, cloth, or other handiwork prepared by the candidate for another guild, and he submitted it to the judgment of a jury of masters. If his "thesis" was adjudged satisfactory, he was given his degree, which in those days meant a license to practice his craft, or in other words, to teach.[5]

The disputation as a test for the degree continued for over five hundred years. At the commencement at Harvard, in 1759, after the salutatory, there followed a syllogistic disputation in Latin, in which four or five or more of those who were distinguished as good scholars in the class were appointed by the president as respondents, and to whom were assigned certain questions which the respondents maintained, while the remainder of the class severally opposed and endeavored to invalidate the arguments presented. This disputation was conducted wholly in Latin, and in the form of syllogisms and theses.[6]

In the old German universities, one of the *Magistri*, as presiding officer, proposed the theses, the other *Magistri* in turn attacking his assumption, with syllogistic arguments; the bachelors as respondents, defended the theses.[7] Typical of the ceremony in Great Britain was the practice at the University of Edinburgh,[8] where: "A thesis had been drawn up by the Regent of the magistrand class, and subscribed to by all the candidates for laureation; and they now in the

[5] E. P. Cubberley. "Degrees in the Guild"; in *History of Education*, pp. 221–22.

[6] C. F. Birdseye. *Individual Training in Our Colleges*, p. 61.

[7] Friedrich Paulsen. *The German Universities*, p. 36.

[8] Alexander Grant. *The Story of the University of Edinburgh*, vol. I, p. 154.

presence of a dignified assembly,... severally bound to defend every proposition in it against all impugners."

Decline of the disputation. With the advent of the scientific movement the disputatory thesis declined in importance. Paulsen [9] explains the decline as follows:

> They (disputations) presuppose two things which no longer exist: first, a community of living, school fashion, of teachers and students;... and second, a fixed body of philosophical principles universally accepted, or, more correctly, an authoritative scholastic philosophy, such as the faculties of arts possessed in the works of Aristotle. Of this, medieval scholars were well aware: *contra principia negantem non est disputandum.* From the sixteenth century onward, these two conditions have gradually disappeared, to become finally extinct in the nineteenth as a consequence of the fact that the disputation first fell into disrepute, and then disappeared altogether.

The change took place gradually, however, and, long before the scientific type of thesis came into existence, disputations and examinations had degenerated into formal exercises and farces. The same theses were debated over and over again by each succeeding generation of candidates. Tutors became proficient in coaching their favorites in "taking off" objections and questions. Visitors often disturbed the exercises by making bad jokes in bad Latin about the candidates. Still the custom persisted for years after the masters had failed to attend, and students debated to empty seats, or to a single associate who certified the exercises had been performed and assured a like service for himself. In the revolt which was led against the outworn and formal traditions of the college, the thesis requirement was in many instances swept away.

[9] *Op. cit.*, pp. 37–38.

The trend of events. As the disputation came into disrepute, a change took place in three different directions: (1) some institutions dropped the thesis requirement altogether, (2) some substituted the written investigation, and (3) some required a thesis based upon original research.

1. Many colleges in this country for a time gave the master's degree without graduate study of any kind. At the University of Pennsylvania, for example, as late as 1852 the regulations read: [10]

> The degree of Master of Arts may be conferred on the alumni of the University, bachelors in the arts of three years' standing, who apply for it.

In a number of other institutions, the degree was conferred upon any alumnus who paid a small amount to the library treasury. In a few Eastern colleges the degree is still granted, from time to time, *honoris causa.*

2. The introduction of printing was a decided stimulus to the development of the written thesis. New fields of study brought new thesis subjects into use. At Harvard, in 1640, an applicant for the "second degree" was required to "give up a system, or synopsis, or sum of logic, philosophy, arithmetic, geometry, or astronomy." A Cambridge student wrote, in 1710: "I have very little time to spare at present, for I am preparing a thesis... being to come up ye beginning of May"; and, by 1761, the regulations specified that candidates for degrees "read their theses before the moderators," with the understanding that the best were to be published by the university. The written form, the greater variety of

[10] *Catalogue of the Trustees, Officers, and Students, 1852–53,* p. 37.

fields included, and the publication of results mark distinct advances over the old oral disputation.

3. With the coming of the new German universities, in the mid-eighteenth century, and particularly after the founding of the University of Berlin (1809), a new type of thesis was created — a type designed to set the academic thesis-pattern for a long time to come. Most significant was the tremendous development of historical research for which these new universities were responsible.[11] First of all, Leopold Ranke of Berlin must be named in this connection as a most influential teacher, after whom comes a long train of prominent scholars in the lines of research which he inaugurated, chiefly in the investigation of "sources" (*Quellenforschung*).

The natural sciences and the thesis. Finally, between 1820 and 1830, mathematical research and investigations in the various fields of natural science began to make themselves more prominent. At Giessen, with only scanty material equipment, Liebig founded a laboratory the results of which proved of the greatest importance, no less for instruction in chemistry than for the practical application of that science. At Berlin, under the leadership of Johann Müller, was developed the new school of physiology, which undertook the explanation of biological phenomena on the exclusive basis of natural science, without calling in the aid of metaphysical principles.

With the growth of the natural sciences in this country, emphasis upon the thesis again began to make itself felt. The master of arts degree still retained much of its old sig-

[11] Friedrich Paulsen. *The German Universities*, pp. 70–71.

nificance — competence to teach; the master of science degree indicated ability in research; the doctor's degree stood for accomplishment in the ultimate essentials of research — ability to make an original contribution to knowledge. At a time when no thesis was required for the master of arts degree at the University of Pennsylvania, the regulations in respect to the master of science degree read: [12]

> Such students as have received the degree of Bachelor of Science (of three years standing) are entitled to the degree of Master of Science, on presenting to the faculty a thesis, which shall give satisfactory evidence that the author has continued to devote himself with success to science.

The scientific movement, therefore, was the next influence that affected the thesis. This movement appeared at Harvard and at the University of Michigan prior to the Civil War, and it received a great impetus to further development through the founding of the agricultural and mechanical-arts colleges under the Morrill Act of 1862. A few years later, 1876, the Johns Hopkins University was established, through an endowment given by a Baltimore merchant, on the German model and as our first distinctively research university. Laboratories, seminars, graduate study, research, and the publication of the results of research have been the leading features of its policy. By the opening of the present century the leading colleges and universities had definitely fixed the thesis as a requirement for an advanced degree, and had distinctly coupled it with research.[13]

[12] *Op. cit.*

[13] This is evidenced by such regulations as the following, taken from the *Register* (p. 34) of the new Stanford University, for its first year, 1891–92: "The degree of Master of Arts will be granted on the completion of an

The meaning of thesis. From the brief historical survey given in the preceding pages one can gather that the term "thesis" has at different times assumed varied meanings. As has been seen, originally it meant a proposition which the student proposed to defend, as when, in 1762, a student at Cambridge as his thesis "affirmed the justice of hell torments and capital punishment." Taken literally, thesis signifies "a thing laid down, a statement, a proposition; specifically, a position or proposition which a person advances and offers to maintain."

A second stage in academic progress was reached when university teachers, notably among the natural scientists, out of patience with the dogmatism and futility of scholastic debate, with its reliance upon authority and deduction, came to hold that a thesis should represent a field of knowledge to be investigated. This group at one time claimed that the investigation, in its whole course, should be presented without comment and conclusion — since it is in interpretation that subjective factors creep in and invalidate the results. They did not object to generalizations inherent in the data, but opposed the addition of anything as true which is the product purely of inference. Data without comment are still regarded by some as constituting a thesis.

additional year of advanced (graduate) work in residence at the university, accompanied by an approved thesis embodying the *results of independent investigation and research.*

"The degree of Doctor of Philosophy will be granted after the successful completion of not less than three years of work after the reception of the Baccalaureate Degree, on the presentation of an acceptable printed thesis which shall embody the *results of original research.*

"Such requirements are practically standard to-day, and represent very well the commonly accepted distinction between the M.A. thesis and Ph.D. thesis. Both require research."

A thesis to-day is commonly regarded as a coherent report of research, in which both the process and the results are given. Its origin is a problem; its central proposition is an hypothesis. In this sense, thesis often is used as synonymous with dissertation (Latin *dissertatus*, p.p. of *disserto*, frequently of *dissero*, to discuss); defined as the "presentation of a subject, oral or written, usually extended and argumentative; thesis, disquisition, hence, in general, extended or didactic remarks or writing." Like *thesis*, *dissertation* has come to connote research, but it is a more pedantic term, and usually is reserved strictly for the thesis for the doctorate. The chief thing to remember is that a thesis is a report of the process and results of research, extending from a central proposition, hypothesis, or problem to a definite generalization growing out of facts.

The meaning of research. The meaning of research, when coupled with the thesis, has also been modified. Originally, and literally, it signifies "a searching for something, especially with care and diligence." The "something" is usually held to be facts, from which principles may be formed. The term comes from the French *recercher*, *re* and *cercer*, modern *chercher*, to search; the act of searching into a matter closely and carefully; inquiry directed to the discovery of truth, and in particular to the trained scientific investigation of the *principles and facts* of any subject, based on original and first-hand study of authorities (primary sources), or on experiment. Investigations of every kind which have been based on original sources of knowledge may be styled "research."

Two points of emphasis are noticeable: the results are

facts and *principles*; and they must not have been discovered before. Severance says: [14] "Research is finding out something, adding something to the known.... Research is the process of discovering something *new*." In *Science*, Dr. E. Emmet Reid writes: "The line is drawn sharply, and the object discovered must not have been known before." Both the ideas of fundamental principles and newness are also stressed by Jacobson,[15] who says:

> Scientific research is the slow, laborious process of laying bare, one by one, the facts and truths of nature, which have a definite bearing upon the *fundamental principles* involved in the problem. The isolation of a *new* chemical compound, the invention of a *new* machine, or piece of apparatus, or the discovery of a *new* force in nature would not necessarily be research. Only as these are units in a larger and more fundamental problem could they be included under that head.

The meaning of research can be explained also by negative definition. Research is *not*: (1) drawing attention to new relations among facts already known; it is *not* (2) deriving the consequences of facts already known; it is *not* (3) developing a body of theoretical doctrine without reference to facts to be accounted for by it. Research employs the inductive method; only incidentally does it have anything to do with deduction.

Types of research. Occasionally the meaning of research is more narrowly restricted to include pure science, as opposed to applied science; to the investigation of causes, rather than to practical experiment. Although the writer

[14] H. O. Severance. "How Periodicals Aid Research," p. 590.

[15] C. A. Jacobson. "Some Aspects of Scientific Research," p. 598.

believes that no such limitation is necessary, nor is such restriction the rule so far as the academic thesis is concerned, yet, since the subject is one of importance, its relations may well be considered here. The chief difference between the two types is not in the process nor in the nature of the results, but rather in the point of view. One who engages in research with the idea of immediate and certain use is said to be engaged in applied research; one who engages in research because of interest in the activity or curiosity as to the results is said to be engaged in pure research.

Applied research is sometimes used in another sense in which it does not furnish a suitable basis for a thesis. For example, suppose a division of labor is practiced in which the scientist discovers the laws, norms, and principles of certain phenomena, and the engineer applies them; the latter cannot make a contribution to knowledge merely by performing the share indicated. He cannot engage in research unless he makes the discovery of the laws, norms, and principles for himself. There is nothing to keep him from doing this, but doubtless greater efficiency results because he specializes in doing, while the scientist specializes in discovery. The point is that, for thesis purposes, he must engage in the work of discovery. The difference here is in the point of beginning, the process, and the results. The pure scientist starts with an hypothesis, collects data, and derives principles; the applied scientist (according to the concept here given) starts where the pure scientist leaves off (with principles) and uses principles in a particular instance or instances. The first could produce a thesis; the second could not.

There is nothing, however, in mere immediacy of use that

keeps the applied scientist from making a contribution. The fact is, the value of most research is independent of whether the worker was actuated by the practical motive or by the curiosity motive. Usually he does not know whether the research will be useful or not; he cannot judge in advance whether it will add to human knowledge or not. Suppose one person starts an investigation with the aim of advancing pure knowledge; another for the purpose of improving production. The methods and results need not differ as a consequence, and neither can really tell whether the values of his work will be greater in its practical applications or in furthering knowledge. The chief thing for the graduate student to remember is that, in scientific circles, usefulness is never adopted as the standard of value, and that, even if not a single practical result is reached by an investigator, the work is worth doing if it enlarges knowledge or increases our outlook upon the universe.[16]

Nevertheless, since an issue often is made between the advocates of pure and applied research, each side may be permitted to state its case. Abbot presents good argument for pure research.[17] He affirms that if investigations had always been limited to the practical we should still be in the dark ages. He continues:

> The enlightenment of the human mind brought about by the study of astronomy, has a value not to be measured in dollars and cents, but by the safety of life and property from religious persecution and by advance from superstition and the ignorant fear of nature. On the other hand, it would be easy to cite many investi-

[16] See R. A. Gregory. *Practical Purpose in Research,* p. 287.

[17] Charles G. Abbot. "Who Will Promote Science?" p. 139.

gations of apparently curious and trivial phenomena which later on came to have high commercial utility. Thirty years ago, no "practical" man would have dreamed of investigating the conduction of electricity through rarefied gases. Roentgen's discovery of X-Rays was not in the least influenced by utility but came out of pure research in that field.

The opposing point of view is well expressed by Cooley.[18] He says that one under the control of the pure research motive is "prone to be swayed by private liking. He who inquires into Nature purely for the pleasure of becoming acquainted with her more intimate forms is especially likely to interpret what he sees in ways pleasing to himself." He defines the practical as "that type of research in which some benefit over and above knowledge itself is hoped for." He believes there is a sense in which "practical" may be used without danger to any one. "It is in the sense of instrumental, or serviceable to a valuable end of some kind, *including the end of acquisition of further knowledge.*" Thus it was a practical motive which led Newton to labor so patiently to determine the precise departure of the moon's orbit from a tangential course. "The satisfaction in view was not primarily the intellectual pleasure of knowing the precise curve itself, but of testing his hypothesis of universal gravitation."

The advocates of pure research reveal their substantial agreement with their rivals by claiming practical values in pure research. Robertson thus justifies the fourteen years of Faraday's laboratory work by asserting its cash value to humanity.[19] He says:

[18] William F. Cooley. *The Principles of Science*, pp. 19–20.

[19] T. B. Robertson. "Cash Value of Scientific Research," p. 143.

According to the Thirteenth Census of the United States the combined income from electric light and power stations and telephones was $360,000,000.... In its waterfall, the United States is estimated to possess 150,000,000 horsepower, which can only be utilized through the employment of Faraday's electric motor. This equals, at the conservative figure of $20 per horsepower per annum, a yearly income of three billion dollars, corresponding at four per cent interest to a capital value of 75 billions of dollars.

A fair resolution of the question is this: consult one's own interests and opportunities. Both types of research are suitable in meeting thesis requirements. If one prefers, like Ogden,[20] to study (1) what is the necessary rest period during the working day? (2) how much sleep is needed? and (3) how much food does a student need? very well. Likewise, he need not apologize if he selects "a microscopic investigation of such subjects as: (1) the classification of the larvæ of the ground beetle, (2) the molecular arrangement in the camphor series, (3) the Fusaria wilt in China asters, (4) and the nature of the ionization of an atom of mineral sulphide." Though one does not know what kind of tree the future will bring forth, he can at least plant the acorn.

The results of research. The results of research have been referred to already as facts, data, principles; i.e. generalizations. The common terms for the results of research are science, or knowledge. Science is of Latin origin; knowledge is of Anglo-Saxon origin; they may be used interchangeably. *Science frequently is defined as knowledge which has been tested and set in order.* Knowledge often is defined as truth. Both embody the idea of orderly, system-

[20] H. N. Ogden. "Purposes of Research," pp. 528–29.

atic, and coherent arrangement of material; a proper concept of science is to regard it as all the careful and critical knowledge we have about anything. It is related to research as results to process.

The last statement can be illustrated by describing the work of the physicist, Faraday. He set out to find under what conditions he could electrolyze water. He first arranged a series of voltameters, having platinum electrodes of varying sizes, from plates to mere wires. On collecting the gas liberated on each separate pair of electrodes he found, in each case, the same quantity. His conclusion was that "when the same quantity of electricity is passed through a series of cells containing acidulated water, the electric-chemical action is independent of the size of the electrodes."

This principle remained true whether he used strong currents or weak currents. It remained true even when the strength of the acid content varied in different voltameters. It did not change with a change in season, passage of time, or any other circumstance. *It is universally true.* He then stated the law, "The amount of chemical action produced depends only upon the quantity of electricity passed." This is now spoken of as Faraday's first law of electrolysis. The experimental process by which this law was derived constitutes research; the law is science. It is usually classified as belonging to the science of physics.

Another illustration may be given. D. A. MacKay wished to determine if some spiracles of insects are used for inhaling while others are used for exhaling. To find the answer to his question, he placed the body of a grasshopper in a glass vessel, the abdomen of the insect immersed in

water, the head and thorax free. In a second vessel, a second grasshopper was placed, the head and thorax under water, the abdomen free. In a third vessel, a third grasshopper was immersed entirely with the exception of the head.

The first two insects remained in a normal condition during the course of the experiment, the third died. The experimenter concluded that no special spiracles are used by a grasshopper for inhaling and exhaling, but that rather all spiracles are alike. Finally, after repeated experiments, he concluded that "the same is true of all insects." The process used is research; the resulting principle is science. It is usually classified in a general way as belonging to the science of biology; it may be more definitely classified by saying it belongs to the science of entomology.

A simple diagram may be used to illustrate further the scientific process and science. A problem is taken as the beginning point. (By problem is meant any condition or circumstance in which one is placed in which he is forced to act (or to know) but does not know how to act (or what to accept as true.) He formulates an hypothesis or postulate. (A theoretical assumption that this or that is true, this or that is the thing to do.) He collects proof of his hypothesis (tests it), by collecting facts, data, observations, phenomena. From these classified observations, he generalizes (states a principle). If he asserts its truth of the particular observations only, the principle is said to be empirical; if it is true of all observations of similar or identical phenomena, it is a universal principle.

1	2	3	4
Problem....	Hypothesis....	Facts, data, observations....	Principle

Classification of science. The subject classification of science is commonly employed. This is to say that all principles having reference to a related body of content are said to belong under the same subject or field of science. Thus all principles derived from research among plants and animals belong to the science of *biology* (*bio* = life — *logy* = science). Physics is the science of force; chemistry of composition. Sociology is literally the science of society; anthropology the science of man. Subjects which refer to nature are called the *natural sciences*; subjects which refer to society and social institutions are called the social sciences. Among the first are physics, chemistry, biology, geology, and astronomy; the second are history, economics, sociology, and political science.

Instead of the two-fold division into natural and social sciences, Robinson suggests a five division system.[21] The first is called *abstract formal science*, comprising the subjects, logic, and mathematics. The second is called *general descriptive science*, including biology, physics, and chemistry. The third is the *special derivative sciences*, comprising ethnology, æsthetics (derived from psychology), botany, and zoölogy, and the like. The fourth group is known as the *synoptic sciences*, with history, anthropology, and geology as typical. The fifth and last group is known as the *applied sciences*, with economics, education, medicine, law, engineering, and agriculture as the chief branches.

Classification for thesis purposes. For the purposes of this volume, a simple classification has been adopted. Its basis is procedure and results. If, for example, the experi-

[21] D. S. Robinson. *The Principles of Reasoning*, pp. 221–24.

mental procedure is adopted, the science is called experimental science. If the normative procedure is adopted, the science is called normative. If the historical method is employed, the science is called history. The typical generalizations or principles obtained through the use of experiment are known as laws (statement of invariable association); of normative procedures as norms (central tendencies, trends) and standards; of historical method as history (statement of probable truth: i.e.,

$$\frac{P' - p}{P},$$

in which P equals all the probabilities for and against, P' the probabilities for, and p the probabilities against).

The discussion is restricted to sciences derived by the inductive process. Logic is therefore purposely omitted because it is not inductive and does not involve research. Probably the same is true of mathematics; or, if it is not true, research in mathematics (for the purpose of making new discoveries) *does not differ from experimental or normative science.* Mathematics, logic, philosophy either are built up by research or they are not. If they are, they come under the classification given of experimental, normative, and historical sciences. If they are not derived by research, their source is either in trial and error or the deductive process, neither of which is research.

A practical question arises concerning the non-inductive sciences: namely, how shall theses be developed in these fields? The answer is: by following the method or methods recognized as valid in those fields. A student in philosophy

may be expected to use the philosophical method, but there is no need of claiming the philosophical method as an inductive process. Of course, the history of any phase of philosophy, logic, or mathematics may be written provided the ordinary requirements as to validity and reliability of sources can be met. A contribution could then be defined in the non-inductive sciences as any new relationships or combinations in generalized form. The writer does not favor accepting the idea that such contributions are *additions to science.*[22]

The true philosopher is more probably one who makes contributions to inductive science, using great care in the process and in his generalizations. Criticism and evaluation to be worthy of respect require the use of the inductive method and the derivation of norms. Real philosophy dates largely from such men as Darwin; the older philosophy deserves no more complimentary designation than that of a pretentious common sense. As to taking the data laboriously compiled by others, re-examining it, criticizing, evaluating — this is a worthy enough activity, but one can claim only partial credit for any new principles thus derived; it gives no complete view of the scientific process. As to deriving theories or super-principles from an examination and evaluation of principles resulting from research, the writer holds persistently even obstinately to the view that the person who has derived the principles originally is best qualified and most likely to observe the larger relationships.

[22] Kelley classifies sciences as biological, physical, social, cultural, and historical. "Reality," he says, "is the standard whereby each is judged. There is a field of human thought quite distinct from this. It is that of logic, pure mathematics, and a certain type of philosophy." (Kelley, T. L., *Scientific Method*, p. 11.)

Any one is ready to grant that there is a vast difference in the degree to which absolute truth is approached, as the result of research, in different research projects. The difference has been expressed by saying that an exact science is like a solar system; a young science is like a nebula. Yet these differences do not so much distinguish subjects and sciences as different research projects in the same science. Some physics is exact; some falls short of absolute precision and truth. The differences are due in part to differences in the subjects or fields in which the investigation is being made; but as great differences are due to the care and accuracy of the individuals doing the research work. The contention is that one may be as scientific in procedure while studying the mental efficiency of consulting pairs as when studying the nature of the green coloring matter in the black spots on a frog's back. In any case, he should not "allow assertion to outstrip evidence, and (he should) understand what he knows." [23] Science includes all knowledge, "communicable and verifiable, which is reached by methodical observation and admits of concise, consistent, and connected formulation." [24]

Values in research. More progress in the advancement of knowledge has been made since the coming of the industrial revolution than in the ten centuries that preceded it. This three-hundred-year period has been preëminently the age of research. Its value is the value of the whole world — at least the difference between the value of the world to-day and the world of the Neolithic savages. It

[23] D. S. Robinson. *Op. cit.*, p. 221.
[24] *Ibid.*

proves a most satisfying form of activity for those who are temperamentally suited for it. As President Wilbur has well said: [25]

> The person who has discovered some new arrangement of forces, some new fact in regard to chromosomes, some fresh chemical combination, the cause of an obscure disease, has thereby become immortal, for his effort has added something which cannot be lost, to the human race. What happier form of immortality than this — to have added something to the world's store of fact and law?

The greatest values in research do not come to one who is ruled by personal ambition. Research requires that humility of spirit which actuated the great teacher, Agassiz, on the Isle of Penikese, who had "come in search of truth." Its fundamental virtue is a passion for truth, whatever it may be, and through whatever channels it may come. As Bosworth declared, "one's only safety consists in a fair treatment of the facts. One fact leads to another, and this to another. Facts treated as they ought to be treated always lead to a larger life. This means not only a larger life for the investigator, but more particularly for the great human family about him."

The graduate student who prepares his thesis wisely and accurately adds a share to the body of science. He performs a special type of research, resulting in (1) laws and principles, (2) norms and standards, or (3) historical probability. For the purpose of satisfying academic conditions, pure and applied research are recognized, and a variety of motives may be presumed to predominate at different times

[25] Ray Lyman Wilbur "Research," in *Science*, n.s., vol. 54, pp. 3–4.

and with different persons. The work of the student investigator becomes one with all of those who have engaged and are engaged in all forms of scientific endeavor.

Summary. The thesis is a nearly universal requirement for a higher degree. During the seven or eight hundred years of its history its meaning has been modified, until as the result it is now intimately connected with the research process and with science. Research is classified as applied and pure, either form of which rightly interpreted leads to the thesis. The facts and principles resulting from research are known as science, and from the point of view of one engaged in preparing a thesis, science may be classified as normative, experimental, and historical. We shall use these terms in the chapters which follow. Various motives may actuate the research worker, but characteristically he has no concern over whether the results will prove useful or not. His concern is to discover the truth.

QUESTIONS AND EXERCISES

1. Find an example of pure research. Of applied research.
2. Compare the two examples called for in (1), and point out resemblances in the methods and results obtained.
3. Select one of the great scientists, and find out what you can about his work. About his personal traits.
4. Some profess to believe mastery of technique, rather than an original contribution to knowledge, is the chief aim in all research carried on by students in training. Discuss the implications of this view.
5. Examine a thesis in your field and note the problem, the method, and the results. Can you classify the method as normative, historical, or experimental? The results as a norm, a law, or history?

6. What is meant by originality. Find out whether there has ever been a scientific study of originality.
7. Read from a history of science and try to formulate reasons for the early antagonisms to science. Do any of these still exist? Can you explain why, or why not?
8. Account for the change in the thesis requirement from oral disputation to a written report.
9. Of what value is research as a means of settling controversies? Of destroying superstition?
10. Explain the chief differences between the requirements for the master of arts thesis and the doctor of philosophy thesis in your institution.
11. Examine a catalogue or announcement of your institution, or of a similar institution of the date 1890, and report any changes in requirements for theses compared with requirements to-day.
12. Suppose the view is taken at an educational institution that applied research begins with a general principle and extends to the application of that principle to a particular case. Would applied research, in this event, really lead to a scientific thesis, scientific in the sense of resulting in discovery?

PROBLEM 1

Settling an Academic Problem

Situation 1: At a recent meeting of the graduate council of the University of Carizona, a member proposed that the thesis requirement for the M.A. degree be discontinued. In defending his position he said:

"The M.A. thesis is useless. It does not involve research, its preparation gives no training in scientific method. No one ever refers to it. My observation has been that in nine cases out of ten it is an essay, a compilation of secondary materials, or a very unreliable study using the case study, questionnaire, survey, or other unscientific procedure and device. It often gives students a false impression as to the meaning and purpose of research, and confirms them in bad technique. A better plan is to have them take courses

where they are called upon to master and assimilate materials gathered, organized, and evaluated by specialists."

Another member of the committee defended the thesis requirement. He pointed out its long history, its change with changing conceptions of university function, and the methods being taken to make it scientific. He declared that there is an overabundance of course work at present, and that the one sixth to one eighth of the total year's credit can well be allotted to an effort to give training in independent work. He admitted that many theses were prepared and accepted which fall short of the standard, but held that this is not due to any defect in the principle but indicates inefficiency in its execution.

After discussion, in which one third of the group appeared to be for the requirement, one third against it, and one third undecided, the chairman appointed a committee to make a report, advising either for or against the requirement, and, in any case, offering arguments that could be put before the entire faculty.

Problem 1–A: What arguments can you offer, assuming you are against the requirement?

Problem 1–B: What arguments can you offer, assuming you are for the requirement?

Problem 1–C: Assuming you are for the requirement, but would like to see an improvement in conditions, what suggestions can you make?

Special questions: (To aid in interpreting the situation)

1. What facts can be admitted on both sides?
2. What is the real issue here?
3. Does the fact that there has been a thesis requirement for so many years argue for its continuance?
4. How do you account for the opposition to the requirement on the part of one of the members?
5. Might the thesis not involve research, and still be better than course taking?

Bibliographical note: There is not much material bearing directly on the question. Some arguments may be found in T. Brailsford

Robertson's "Cash Value of Scientific Research," and in W. D. Scott's "Discovery of Truth in Universities." Ray Lyman Wilbur takes up the value to the individual in "Research"; Robert McDougall in "University Research." Robert A. Millikan discusses the subject in *Science and Society*. See also Selected References, Benedict, F. G., Boas, F. S., Grier, N. M., Jacobson, C. A., and Ogden, H. N.

On the other side of the question, it would be a good idea to examine textbooks to see if theses are referred to, and to examine a random sampling of theses to find out if what has been said is true. Perhaps, instead of the thesis requirement, there might be substituted a laboratory course, or a course in statistics.

Directions for solution: (Until other instructions are given, follow the form below in presenting your solution)

1. Statement of problem.
2. Statement of any assumptions necessary to solution.
3. Solution given in detail.
4. Summarizing principle.
5. List of references used.
6. Exploration activities, including:
   a. New references discovered.
   b. New situations and new problems.
7. Time schedule, under these headings:
   a. Preparation.
   b. Writing report.
   c. Exploration activities.

PROBLEM 2

Sources in Various Fields of Science

Situation 2: At a meeting of the research council of the University of Illaowa, the usual subject of ways and means of encouraging research interests among students arose.

One of the members made a remark that created considerable discussion. "In every field of knowledge," he said, "there are individuals and groups making collections of facts and figures.

These should be classified and interpreted, but those who do the collecting do not have the time, and occasionally do not have the talent, to give meaning to their data.

"I refer particularly," he said, "to official gatherers of facts, whether they be persons who tabulate and report for our national departments, or whether they keep the record of a scientific expedition. To be explicit, how many graduate students are there in sociology and economics who know what is contained in the census reports of the department of commerce? How many know what other official documents are issued regularly by this department and the department of labor?

"The importance of a knowledge of the range of sources in one's field was brought home to me recently through observing a seminar group in United States history. The special field was diplomatic relations between England and the United States during the Civil War. The special issue turned about the knowledge the United States possessed concerning the building of ironclads for the Confederacy in a Liverpool shipyard, yet out of a class of twenty only one thought of using the reports of the United States consul at Liverpool as a source."

Although the general opinion was that the criticism applied to normative and historical science, and not to the field of natural science, yet the point was made that there are many documentary sources in the field of natural science of which scholars should be aware. As a result of the discussion, an agreement was reached to bring the matter to the attention of the faculty, with the suggestion that they individually find the opportunity of acquainting their graduate students in a general way with the sources in their respective fields.

Problem 2: Select some narrow division of your field of interest and report the sources available in it, giving titles and kinds of information they contain.

Special questions.

1. What is meant by a source, as the term was used by the member of the council?
2. Is there any point to the remark that a scholar needs to know from whence the content of his field of study comes?

3. Was the use of these sources for thesis purposes contemplated, or was the council simply interested in having students know what and where and what kind these sources are?
4. Should a student in history be expected to know of consular reports? Should a student in any other field be expected to know the same?

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CHAPTER II

THE PROBLEM AND ITS INTERPRETATION

The meaning of problem. A thesis properly begins with a problem. This signifies a situation which can be resolved by no past habit pattern, thus necessitating a new form of action. The term comes from the Greek, *proballein*: anything thrown forward,... a question proposed for solution; a matter stated for examination or proof; a matter difficult of solution or settlement; a doubtful case or question. Problem is frequently used as synonymous with project. The derivation of the latter is identical, except that it is from the Latin and seems to have been modified to mean: "to throw forward in a prescribed direction." Woodworth brings out the psychological aspect very well in his definition of a problem as "a situation for which we have no ready and successful response by instinct or by previously acquired habit. We must find out what to do." [1]

In any situation in life there are pronounced interests which take the form of definite images of some achievement or end to be effected. The resulting associations in abler minds are directed towards the means by which the ends may be realized. In simple situations, and among persons who respond in habitual ways, the end readily suggests the means. In new, complex, and striking situations, and among persons gifted with that rare insight and originality

[1] R. S. Woodworth. *Psychology. A Study of Mental Life.* Quoted from M. T. McClure. *How to Think in Business*, p. 28.

that make old habits unsatisfactory, the search for new means is begun; in other words, research begins. Dewey expresses nearly the same idea when he says that every conscious situation involves the possibility of a change. "The need of clearing up confusion, of straightening out an ambiguity, of overcoming obstacles, of covering the gap between things as they are and as they may be when transformed, is, in germ, a problem."[2]

Problem illustrated. In Huxley's *Journal* is an entry, on October 5, 1840, which illustrates problem. "Began speculating on the cause of colors at sunset," he wrote. "Has any explanation of them ever been attempted?" Likewise, Pupin thus describes Joseph Henry:[3]

> But watch him in his work! How does he start? He starts with the problem of making a better electromagnet than any ever made — not an ordinary one. If one wishes to make a real advance in any line, he must know what other people have done in that line. Henry read everything that other people had done in constructing a fine electromagnet.
>
> Henry observed that he got a much larger spark when he broke the circuit.... There came to his mind immediately something which had never suggested itself to anybody else's mind: namely, self-induction.

The idea of atomic structure came to the mind of Dalton as a "purely physical conception, forced upon him by studies of the physical properties of the atmosphere and other gases." He believed that chemical combinations consist in the approximations of atoms of definite and characteristic weight. He was led to this belief by his search for an

[2] John Dewey. "Problem," in Monroe's *Cyclopedia of Education.*

[3] M. I. Pupin. "The Meaning of Scientific Research," p. 27.

explanation of the law of multiple proportions. In his experiments he discovered that water would not absorb all gases to the same degree, and decided that this was due to the manner and weight of the particles making up the different gases.

Dalton then analyzed water, ammonia, carbon dioxide, etc., and determined the relative weight of the ultimate atom of various substances. He was next confronted by the problem of ascertaining the relative diameter of the particles of which he was now convinced all gases were made. He had recourse to chemical analysis. Going on the assumption that combinations always take place in the simplest possible way, he arrived at the conclusion that chemical combinations take place between particles of different weights. The extension of the idea to substances in general led him to the law of combinations in multiple proportions: "The elements of oxygen may combine with a certain portion of nitrous gas, or twice that portion, but with no intermediate quantity."

In 1865, when Pasteur was forty-three years old, he was asked to investigate the silkworm diseases that were threatening the silk industry of France. To his plea of ignorance and his statement that he had never seen a silkworm, Dumas, acting for the Senate committee, answered, "So much the better. You will not have any ideas except those that come to you through your own observations." Thus a man, known as a chemist, left his studies on fermentation and entered the realm of zoölogy. Within five years he had isolated the essential factors in the silkworm disease, had worked out a technique for applying the knowledge, had

demonstrated the efficiency of his method, and had solved one of the great economic problems of his country.

One more illustration of problem-solving will suffice. In 1845, the French astronomer, Le Verrier, began a study of the movements of the planet Uranus. Since 1690, observations had shown that the position of the planet at various times did not agree with its orbit as calculated by Herschel, soon after his discovery of the planet. After having studied these facts carefully, and after having convinced himself that the irregularities were not due to errors in observation or calculation, Le Verrier advanced the assumption that these disturbances were due to the attraction of another planet exterior to Uranus. This theory was only one of many that were being advanced at that time to explain the irregularities which had been observed. *To find the right explanation was the problem of each man.*

The purpose of the problem. Although knowing what a problem is may be regarded as the first step in selecting a problem, one other point deserves notice before proceeding to the search. As has been suggested, there are many suitable problems; ordinarily there is an opportunity for choice. One's choice is in a large measure determined by something more than chance; in fact, by purpose. The first and leading purpose of the student, since the problem is to be used as the starting-point of a thesis, is *to find something that will enable him to meet an academic need.* Unless his problem will do this, he should make a new choice, or abandon, at least for the time being, his aim to attain an advanced degree.

Universities, however, do not insist upon graduate students preparing theses merely to put an obstacle in their

path to the degree. The requirement is not simply a formal one; it does something more than serve as a selective device. The university insists upon the thesis because there is a belief that it affords valuable training, that it forms a good test of scholarship and research ability, and that it may promote some worthy purpose of the investigator. It believes that worth-while additions to science are often made by the research of students. The student may be actuated by one motive, or by many. Accepting the situation as it is and making the most he can out of it, a student may select a problem because its solution enables him:

1. *To satisfy a personal interest or curiosity.* If this motive is present, no other is necessary. If it is lacking, thesis-making is likely to become a perfunctory, formal task, the results of which are barely on a passing level. Interest and curiosity indicate that the problem is the student's own, and that his pride will not rest until he has done his best. To discover how Terence used the ablative, to find the torsional stress distribution in prismatic bars, to find the composition of the ash of the sea lion — all are worth while as thesis problems, *provided* the students who attack them do so from the desire to know.

2. *To furnish a basis for confirming some earlier study, or a basis for some future study.* Many research workers prefer to lay the foundations for their superstructures, or refuse to accept those laid by others until the materials have been tested. Within limits, this attitude is entirely defensible; it was the attitude of Faraday, of Newton, of Pasteur, and of Agassiz. Every new advance made also brings in doubts as to the validity of the old, as well as new opportunities.

The relativity theory of Einstein, the development of a device for measuring intelligence, the unearthing of remains in Egypt — these provoke the type of studies indicated.

3. *To meet a social need.* This type of problem is exalted by those who favor applied research. Protection against disease, the prevention of wars, the adjustment of labor disputes, the improvement of institutions, or the adding to comforts and conveniences are illustrations of this type of problem. This is the type of research praised by Tolstoi.[4]

> Real science lies in knowing what we should and should not believe; in knowing how the associated life of man should and should not be constituted; how to treat sexual relations; how to educate children; how to use the land; how to cultivate it oneself without oppressing other people; how to treat foreigners; how to treat animals; and much more that is important for the life of man.

4. *To serve a utilitarian purpose.* This aim overlaps the preceding, but includes particularly those objectives that are personal and individual. For example, one may prepare a thesis that will further him in his vocational ambitions, he may write a thesis that may be made the basis of a book, or he may perfect a labor-saving device. The last is commonly looked upon as an invention, not as a discovery; the inventor is not regarded as a scientist unless he seeks for and finds ultimate principles.

Thesis problems illustrated. Fifty years ago a writer in a mathematical journal declared that all the discoveries in the field had already been made, and that the activities of mathematical scholars in the future would be devoted to filling in the gaps. This prophecy, however, proved to be a

[4] Lyof N. Tolstoi. *What is Art?*, p. 178.

false one. The range of suitable topics seems to be as wide as human interests and needs, and, although it is unquestionably limited, the chief handicap is not lack of problems, but deficiency in human intelligence and discernment. The student may supply evidence of as high a degree of originality in the discovery of his problem as in its final solution.

The variety of interests and of opportunities is readily observed by an examination of a sampling of thesis subjects. Another obvious point is that there is often some discrepancy between the problem and the subject field in which it is classified; for example, a physiological problem may be worked out in the psychology department. This is not a matter of concern; the important thing is to find the problem and then to work it out wherever conditions are most favorable. Problems nearly always cut across subject fields; they are less artificial than the classifications of men. As illustrations of topics which have served students in the past, the following are given as typical:

Typical Thesis Subjects

	Subjects	Department in which Written
1.	Science in Modern Romance	English
2.	Mæcenas Elegies in the Appendix Virgiliana	Classical Literature
3.	Torsional Stress Distribution in Prismatic Bars	Physics
4.	The Effect of Loss of Sleep	Psychology
5.	The Question of Northern Albania or Epirus	History
6.	Primitive Groups Which Contain Substitutions	Mathematics
7.	The Congenital Behavior of the Guinea Pig	Psychology
8.	The Sugar Market of the United States	Economics
9.	A Measure of Mechanical Ability	Education
10.	Physiological Action of Bacillus Botulinus	Medicine
11.	Deterioration of Linotype Metal from Use	Metallurgy
12.	The Formation of Urea from Amino-Acids	Chemistry
13.	Divorce: A study in Social Causation	Sociology

TYPICAL THESIS SUBJECTS

Subjects	Department in which Written
14. Viscosity Values of Protoplasm	Biology
15. The Cutaneous Glands of the Common Toad	Zoölogy
16. Fusaria of Potatoes	Agriculture
17. Origin of the Moving School in Massachusetts	Education
18. The Thysanoptera of India	Entomology
19. Theory of the Motion of the Small Planets	Astronomy
20. The Problem of Omnipotence in Current Theology	Theology

Additional criteria for thesis subjects. Although one might by analogy derive useful thesis subjects, he needs in addition checks or criteria to help him estimate their probable worth. The submitting of the problem, at an early stage, to certain approved tests may lead to a change to a type better calculated to meet the academic need; that is, to fulfill local requirements. A few years ago, a student in one of our large universities submitted his completed thesis to the graduate council. The council refused to accept it on the grounds that it was not a contribution to knowledge. In defending the thesis, the student contended that a contribution to knowledge may be made by: (1) adding new facts and principles, (2) adding new techniques, and (3) by making available to the many what was before available only to the few. His thesis, he felt, measured up to the third criterion; but the council refused to accept the validity of the third principle.

While such a possibility as has been described above is a factor always to reckon with, thesis subjects which partake of the nature of the following are usually acceptable:

1. Accumulated facts pertinent to some live issue: i.e., state

income tax legislation, or the enforcement of national prohibition.

2. New facts on any subject of basic significance: as, the extent of the habit-factor in the sleep requirements of adults, and the life history of the water boatman.
3. New implications and therefore new generalizations from previously discovered facts: as, the relation between income and intelligence, and nature *versus* nurture as calculated from achievement test results.
4. Verification studies, especially when the probability of new generalization is strong: as, relation between physical development and mentality; and influence of the frontier upon American history.
5. Executive studies, especially the administrative thesis: as, farm-marketing, the location of cotton mills, the selection of department store workers.
6. Salesmanship or program studies: financing the building of highways, or the reorganization of county government.
7. Liaison theses: involving coöperative agencies and checks and balances: i.e., the bicameral legislature, or the world court.

More definite criteria may be derived by considering a special case. A school administrator, wishing to expand the vocational program in his junior high school, was particularly favorable to the idea of offering courses in occupational information and of offering vocational guidance. He believed he could induce the school board to supply the funds necessary to carry out the program by pointing out the beneficial effect of the life-career motive upon study, scholarship, citizenship, and attendance. He found this view to be commonly held, and he traced its pronouncement to Charles W. Eliot, formerly president of Harvard University.

Wishing to have facts from his own school to support his hypothesis, he began to study the problem experimentally,

and labeled it "The Influence of the Life-Career Motive." When his preliminary data were assembled, he found, to his surprise and chagrin, that the popular view had not been sustained. Here then was a suitable problem for further investigation.

An analysis of this study reveals these characteristics — all of which may be used as criteria in problem selection:

1. An apparent conflict between the results of a preliminary experiment and authoritative opinion.
2. A challenge to originality in technique, and care and accuracy in treating results.
3. A probability that the results would finally produce changes in educational theory, organization, and practice.
4. Uncertainty as to what the ultimate findings would be.
5. Probability of deriving a general principle concerning the influence of motive upon human behavior.
6. A topic definite enough to permit concentration of effort upon a single point.
7. Curiosity among people in general concerning the results.
8. Possibility of opening up a new field of investigation, and discovering a number of new problems.
9. Opportunity of a life work in the new field.

A survey of the past shows that old theories need to be subjected to examination by each succeeding generation. Aristotle taught that all heavenly bodies revolved around the earth. Galileo doubted the truth of the theory, and determined to test it. He needed first an instrument that would enable him to observe the movement of the planets. He perfected the telescope, and, turning it upon the heavens, made discovery after discovery that controverted the ancient philosophy, and added proof to the opinion of Coper-

nicus and to his own doctrine. He turned his telescope to Jupiter and, to his amazement, found four moons revolving around it. His hypothesis had become truth.

At this stage Galileo met with an experience so typical that its occurrence may almost be given as an infallible assurance of the validity of a contention: he met the disbelief of his contemporaries. One of his colleagues reasoned that, since the moons were invisible to the naked eye, they did not exist at all. Another refused to look through the telescope. A third declared: "I have looked through Aristotle and can find nothing of the kind mentioned. Be assured, therefore, that it is a deception of your eyes or of your glasses."[5]

Sources of problems. As music lies in the ear of him who hears it, so thesis problems are in the minds of those who perceive them. One who is fruitful in discovering problems is quick to discern likenesses and differences. He is sensitive to incongruities in reasoning, and recognizes on the instant doctrines which are at variance with scientifically established principles. He is responsive to conditions which interfere with coherent thinking and the smooth working of human relations and associations. Keenness of perception and persistence in exploring for clues are conspicuous traits. His watchwords are empiricism, pragmatism, skepticism; though the latter is subdued, it carries a courteous disinclination to accept conclusions without assurance that their bases are on the solid ground of facts. He is not thrown off his balance by a quotation from Saint Augustine, nor will he accept a fine Greek compound as a substitute for

[5] Ivor B. Hart. *Makers of Science*, p. 116.

truth. Though he may keep his gallantry, he has lost his naïveté.

Next in value to such inherent or habitual traits as have been mentioned, comes the practice of going where problems are. The great storehouses are nature, human activity, and the records of nature and human activity. One should not exclude altogether his own experiences and observations. He should run over in his mind the controversial questions of which he has become aware. He should look for subjects in fields where information is scarce or indefinite. Any question answered by "I do not know" possibly furnishes a research problem, particularly if the answer is given by a specialist in the field. One should not accept blindly the traditional views of society, nor of his profession. He should inquire zealously into the basis for current doctrine. No belief is so sacred and no faith so pure as to be worth more than the truth.

One other requisite to finding research problems should accompany good personal traits and the habit of critical appraisal of the present. It is the habit of mastering the entire chain of events connected with the development of each narrow division of one's chosen science. Knowledge of the general history of one's science is not enough — for example, the history of chemistry, the history of psychology. One needs to know in detail each particular research project in a series. Marconi knew every step in the transmission of messages by electricity. He made a close study of Hertzian waves. He eagerly devoured any book or periodical or any report of original research which was in the line of his interest. He formulated the hypothesis that electric energy

passes through any substance and, when started in any direction, follows a direct course without the assistance of any set of conductors. He had found his problem.

Faraday supplies another illustration. He says: "I had a very lively imagination and could believe in the Arabian Nights as easily as the Encyclopedia. But facts were important to me and served me. I could trust a fact, and always cross-questioned an assertion." Here are two important requirements of a research worker: a keen and lively mind, quick to detect problems and formulate hypotheses that would not occur to one whose mind runs in orthodox grooves; and a strong regard for facts, a tendency to be critical of an assertion. Imagination alone makes the dreamer, the theorist. Facts alone may have little meaning, may lead nowhere. Faraday was fertile in setting problems, but he was very rigid in testing his assumptions. He hated doubtful knowledge. "Be one thing or another," he seemed to say to an hypothesis; "come out as solid truth or appear as a convicted lie." With these characteristics went the practice of assimilating everything that had a bearing upon his interests.

Classification of sources. The general classification of sources as: (1) nature, (2) human activity, and (3) the records of nature and human activity, is too broad to do more than point a direction. Each division should therefore be broken up into its branches or subjects, as nature into physics, chemistry, zoölogy, and botany; and each subject into smaller divisions until the individual problems underlying the science have been reached. Proceeding in this way, one will consult of necessity such sources as the following:

1. *Courses.* Every course taken by a graduate student should suggest many unsolved problems. He is bound to be aware of topics on which data are scanty, and principles indefinite. As these are met, a record should be made of them for future consideration. The consideration may consist of: (1) finding out what research has been carried on, and (2) discussing with the instructor the significance of the problem which has been formed. Often the instructor calls attention to unsolved problems, sometimes special sessions of the class are given to their consideration. If the class is taught by the seminar or by the problem method, students often make a beginning in research on individual topics. Special assignments and term papers also often suggest thesis problems.

2. *Books.* Books are another fruitful source of suggestions. Not only are problems specifically mentioned in the text, but the author frequently prepares special lists which either are or suggest problems. They may be included as special assignments, or may serve as teaching exercises. If not specifically enumerated, problems may be indicated in a general way, as the following classification of problems of national welfare indicates: [6]

> (1) Problems concerning the relation of this to other nations, (2) national problems, (3) problems concerning the relations between the nation and organizations within it, (4) problems relating to organizations, (5) those concerning the relations between organizations and individuals, and (6) problems relating to individuals.

Other books treat nothing but problems: problems of the

[6] P. G. Nutting. *The Application of Organized Knowledge to National Welfare.*

teaching profession, problems of psychology, problems of sociology, problems of chemistry. Almost no textbook fails to call attention to contradictions or differences of opinion concerning facts and principles in the fields it treats.[7]

3. *Periodicals.* Periodicals offer a third source. Their contents should first be sought through the reader's guide and similar indexes. Merely perusing the table of contents will serve to indicate what people are talking about, writing about, and studying. Reviews and abstracts of scientific investigations appear in all scientific magazines. The presence of symposiums always indicates a lack of accurate knowledge on the subject being discussed. There are, moreover, mentions of prize awards for research, of programs of conventions, of research completed and under way, and of problems which should be attacked. Typical of articles dealing wholly with problems is one cited herewith on astronomy, with four of the many problems suggested, selected at random, for examples:[8]

1. No one has been able to suggest an explanation that is at all satisfactory for the bright streaks that radiate from several of the great craters (of the moon) like Tycho and Copernicus (p. 194).
2. Why has Saturn, and Saturn only, that beautiful ring system? (p. 195).
3. We are eager to know all about sunspots. Why do they appear at all? Why does their number vary periodically? (p. 197).
4. What is the source of all this energy? (of the sun) (p. 198).

[7] Arthur Dendy (ed.). *Problems of Modern Science* is an example of a book that discusses several fields open for investigation.

[8] Robert G. Aitkin. "The Solar System — Some Unsolved Problems."

4. *Proceedings.* The proceedings of boards and learned societies representing one's science should also be examined. Papers presented at such meetings are often tentative, and seldom complete. Often they are not followed up by further study. Reports of committees may enumerate questions of grave concern to the whole body. In dealing with published materials of this sort, and books and magazines as well, there is an advantage in making a tabular analysis of the research, over a period of years. Such an analysis of the proceedings of the National Education Association from 1874 to 1926 was made by the writer, revealing a whole host of problems. Among the total, one could discern those of frequent occurrence and those which tended to recur from year to year.

5. *Lists of theses.* Of similar nature are the lists of research topics and theses published annually. In political science such a list will be found in an annual number of the *Political Science Review*; in economics in the *American Economics Review*; in sociology in the *American Journal of Sociology*. Similar lists may be found in the journals devoted to the special fields.... The Department of Historical Research of the Carnegie Institute publishes annual lists of doctoral dissertations in history at the chief American universities. In the sciences, the "Reprint and Circular Series," of the National Research Council, gives a list of the doctorates in science. The Bureau of Educational Research, University of Illinois, publishes a list of M.A. and Ph.D. theses in education, and a similar list of research studies may be obtained from the United States Bureau of Education.[9]

[9] See H. O. Severance. "How Periodicals Aid Research," p. 590.

6. *Historical analysis.* The method of historical analysis can be applied also to a single field or problem, as well as to periodicals and proceedings. This method was followed by the National Tuberculosis Association.[10] After an investigation of the nature and extent of research in tuberculosis in hospitals, the committee decided that the first necessity was the choice of specific problems. This meant a study of the evolution of research in tuberculosis, a decision as to the most important problem yet unsolved, and a determination of the most hopeful leads towards the goal. A similar suggestion was made to Sigma Xi [11] in the following statement:

> Become thoroughly acquainted with the history of your problem. Become well oriented and familiar with the principal theories and conclusion of others who have approached your problem.

7. *Conferences.* The conference is another method of discovering problems. Conferences may be held with instructors, with fellow students, and with persons of scientific interests outside of the university. The approach may be a question: "What do you think of the explanation of ......?" or by more direct inquiries such as: "What are the chief problems in ......?" The greatest value in conferences, however, is not in uncovering new problems, but in clarifying and interpreting ideas which the student has not yet analyzed. To clarify a half-formed problem, one of the best questions to ask is, "How would you suggest attacking such a problem as......?" because no answer can be given until the problem is clearly stated.

[10] W. C. White. *Coöperative Research — the Plan of the National Tuberculosis Association.* p. 266.

[11] Bird T. Baldwin. "Sigma Xi in Research," pp. 7–8.

8. *Investigation.* A final method of finding a problem of one's own is to begin an investigation of any problem in which one is interested. In the course of the study, new problems are almost certain to appear. Pasteur would start one problem and isolate the essential facts. As he progressed, everything he did seemed to open up new fields to him. He was as absolutely independent of any walls of division between different sciences as is Nature herself. He overthrew the theory of spontaneous generation; and he saw the applicability of this work to the study of diseases. In his words, "Science advances one step, then another, then draws back and meditates before taking a third," he seems to sum up his method of reaching new problems. At all events, it is highly important to get the process under way as a means of finding one's real field.

The techniques of problem-finding can be summarized briefly under four heads:

1. Analyze what is known, including the historical record;
2. Look for gaps or deficiencies in explanations — that is, for "areas of darkness";
3. Watch for incongruities and contradictions, the points of controversy, the untested conclusions; and
4. Follow clues and suggestions obtained from reading, conferences, and thinking. Observe where activity is greatest, and where there is evidence of neglect. Keep a memorandum of ideas, hypotheses, and problems as they occur.

Practical suggestions. A problem should not necessarily be rejected because no avenue of approach or method of solution is seen: these may arise after work is commenced.

Successful puzzle-solvers uniformly commence to manipulate the device as soon as it is put into their hands. They think as they work, they observe, they at length get the clue, and finally they discover the principle. Begin work if it is nothing more than to analyze the problem, formulate hypotheses, or read what has been done on related questions.

Practicality is not to be entirely overlooked, however. The time available in which to prepare a thesis is often decidedly limited. Some universities require its completion within a year after the course work is finished. Such a requirement necessitates a narrow problem, on which sources or data are easily available. It warns one against attempting something beyond the range of his time, abilities, and finances. If, however, the postponement of the degree is of less importance than satisfying one's self in respect to his research, the degree should wait.

The three essentials to be looked for are: (1) the right kind of problem, (2) a plan of solution, and (3) freedom. The problem, then, should be one's own. Indeed, originality is expected in the doctor's thesis; it is highly desirable in the master's. Of course, the student can learn technique of research by working on a problem that others have worked on time and time again, but he will not do his best until he works on a problem that is new. He needs to feel the joy of discovery, and to feel pride in possession.

Independence is regarded as an absolute *sine qua non* in all theses, but university regulations specify that when the student is engaged on a thesis he shall accept the supervision of an adviser. The function of the adviser is chiefly to see that the thesis meets university requirements and

measures up to university standards. The responsibility for planning, executing, and organizing the thesis rests with the student. In order that the adviser may know the progress being made, the student should consult with him, from time to time, and particularly when: (1) the problem has been selected and stated, (2) when the literature of the subject has been reviewed and the bibliography prepared, (3) when a plan of work has been outlined, (4) when the results have been arrived at, and (5) when the thesis has been written in preliminary form. The appearance of unexpected difficulties or discoveries warrant other conferences.

Statement and analysis. The proper statement of a problem helps one to estimate its value, determine whether it has been limited sufficiently, and to suggest methods of solution. A broad general subject is unsuited to research; it should first be fitted to a narrow, definite compass, presenting but one issue. A general subject invites general treatment; a narrow subject admits of detailed treatment and solution. Probably the best way to formulate a problem is as a question. If a problem will not stand transformation into a definite question, it should be restricted until it does become definite. "What are the causes of endemic goiter?" may be a suitable thesis problem, but it becomes better suited to research when one asks, "Does a protozoid cause endemic goiter?" or, "How can endemic goiter be experimentally induced?"

The analysis of problems is discussed in a later chapter. At this time, it will suffice to say that analysis consists in giving tentative answers to the question proposed. For example, suppose the thesis problem is, "What are the

effects of loss of sleep?" the assumptions may be that loss of sleep results in: (1) lowered mental efficiency, (2) reduced weight, (3) nervous instability, etc. Or, if the problem is, "What are the mental effects of loss of sleep?" an analysis would be made by such statements as: (1) it decreases the rate of association, (2) causes a decline in ability to deal with abstractions, (3) lowers the power of sensory discrimination, etc. By such means the unity and completeness of the investigation may be maintained and the ease of presentation increased. The process should not be hastened too much, for time is needed to insure that the divisions are balanced and related to the main issue.

Summary. A thesis begins with a problem. It may be defined as a question proposed for solution by research; and particularly as a situation which compels a new type of behavior. One problem may be selected rather than another: (1) because of its interest, (2) as a basis for further study, (3) to improve social conditions, (4) to further personal ambitions. New facts on live issues, on basic subjects of permanent significance, new implications of old facts, verification of accepted principles, and the various kinds of administrative programs all rest upon the solution of problems. The sources are everywhere, but may be brought together under three topics: (1) nature, (2) human activity, and (3) the records of nature and human activity. Books, courses, periodicals, proceedings of learned societies, lists of theses, historical analyses, conferences, and surveys of scientific studies of all kinds may lead to the discovery of thesis problems.

QUESTIONS AND EXERCISES

1. Study the life of some great scientist, and explain the situations which finally led to his finding his life work.
2. Does the writing of a report upon all the research work that has been done on a given problem constitute a thesis? Is the beginning point of such a report a real problem?
3. Try to explain the great emphasis placed upon interest and curiosity as motives of research. Is such emphasis justified?
4. A good many university teachers hold that the mastery of the technique of research is the chief aim to be realized through the thesis. If this is true, they contend, it really makes no difference whether the problem is a new one or not. Discuss this point of view.
5. Students are often advised to find a problem that will lead them into a wide field in which they can work for years in the future. Is such advice good? Discuss.
6. Is an invention to be regarded as an acceptable thesis contribution? Suppose it supplies a new tool of research?
7. What can you say about pronouncements that there are no more unsolved problems in certain fields?
8. Examine a few theses and note: (1) whether there is a real problem or not, (2) what the apparent motive of the writer is, and (3) the field to which it belongs.
9. Examine a thesis and pass judgment upon whether it is a contribution to knowledge or not. Does it add new facts and principles? new techniques? Does it make available to the many what was before available only to the few?
10. Examine the *Reader's Guide* under headings connected with your special interests. What topics seem to be discussed most frequently? Is there much research being published in your field?
11. Set down a few controversial subjects in the field of your chief interests.
12. Some one has said that one of the main functions of science is to settle controversies. Does this statement suggest sources of problems?

13. Make up a list of criteria to consider in deciding whether to accept or reject a problem.
14. Summarize the technique of problem-finding.

PROBLEM 3

Finding a Problem for Study

Situation 3: Mr. James R. Williams is a graduate student in psychology at Carizona University. He is chiefly interested in learning studies. At the opening of his second quarter of graduate study he is required to submit a thesis problem for approval. He has three problems in mind, in all of which he is interested. He is anxious to put the best one before his adviser, or, if none appears to be satisfactory, he wishes to submit another.

In talking the matter over with a fellow student, Mr. Wells, the latter said: "Tell me what your problems are, and I shall give you my best judgment of their value."

Mr. Williams gave the following problems:

1. A study of learning to walk a slack wire.
2. A study of ability to estimate the passing of time, i.e., the time sense.
3. Influence of motivation on the rate of learning nonsense syllables.

Mr. Wells objected to the first and third on the ground that they have no practical value; to the second, on the ground that it cannot be studied scientifically. When asked to rank the subjects, he gave first place to time study, second to walking the wire, and third to motivation of learning nonsense syllables. Mr. Williams still remains undecided as to which is the best problem, or whether any one is satisfactory.

Problem 3-A: What advice and suggestions can you offer him to help him reach a sound decision?

Problem 3-B: Can you submit some other problem in his field and justify its substitution for any of three, or can you submit, as illustrative of what he should have, a problem in some other field?

Special questions:

1. Does it make any difference whether the results can be applied or not?
2. Is the objection that a problem cannot be studied scientifically a justifiable one? Should the objection of impossibility be urged if a person really wants to study a problem?
3. What criteria can you turn attention to in helping Mr. Williams?
4. Is it advisable for a student to talk over his problems with others? Should he be discouraged if they are criticized?

Bibliographical note:

Reference might be made again to articles on applied *vs.* pure research. In the list of references, see Bingham, E. C., Good, Carter V., and Trow, W. C. V. A. C. Henmon has an article on "Needed Research in the Field of Learning"; in *Journal of Education Research,* vol. 11, pp. 313–21. (May, 1925.)

PROBLEM 4

WHAT IS A PROBLEM?

Situation 4: Professor Wilson, of the University of Illaowa, is preparing a course in Business Administration to be taught by the problem method. He has defined problem much as in this chapter, except that he has not expected his students to engage in extensive research in order to solve the problems, or any problem. He has, generally, made his references to magazine articles and textbooks; occasionally he has listed an original source, such as an official document. He recognizes that he has prepared teaching problems — not research problems.

In talking the matter over with a colleague, his colleague declared that there is and can be no distinction between a teaching problem and a research problem. He maintained that, if a solution is available, a problem no longer exists.

Professor Wilson, however, insisted upon making the distinction, holding that in the case of a good research problem there should be a chance to add to the store of knowledge, while in a teaching problem the assimilation of knowledge is the chief aim. He agreed that

a consideration of the question by graduate students should constitute a good assignment; one that would have the effect of training the student to judge between a good thesis problem and one that is not a good thesis problem.

Problem 4: Assuming you are a member of Professor Wilson's class, show how to distinguish between a good research problem and one that is not a good research problem.

Special questions:

1. May a situation involve a problem for one person without its constituting a problem for another?
2. Is there a final solution for any problem?
3. Are the problems given at the ends of the chapters in this book research problems, or teaching problems?
4. Would it be a good idea to illustrate by comparing problems that have been used in theses?

Bibliographical note: An analysis of several problems that have been used is doubtless the best method of approach to this problem. A check list of criteria developed from reading and other experience might be applied. The problems in this text are designed for teaching. As a part of the solution, it would be well for the student to see what materials he can find not cited in references in Chapters II and III.

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CHAPTER III

THE SCIENTIFIC METHOD

1. *What is the scientific method?*

The expert pursuit of knowledge. After the thesis subject has been decided upon, the question naturally arises, "How shall I attack it?" "How shall I find the truth concerning this problem or proposition?" There is but one general answer, "Use the scientific method." When the further question is asked, "What is the scientific method?" the student learns that "method" is derived from the Latin, *methodus*, and the Greek, *methodos*; *meta* = after, and *hodos* = way; thus a general or established way or order of doing or proceeding in anything, or the means or manner by which such a way is presented or inculcated; as, a *method* of pronunciation. *Scientific method,* a mode of applying logical principles to the discovery, confirmation, and elucidation of truth. *Method* is also used to signify *pursuit of knowledge,* while scientific is used to signify *expert. The expert pursuit of knowledge,* then, comes as nearly defining scientific method as is possible in a few words.

In a broad sense, scientific method is used by every one. The chief difference between the scientist and the layman is in the degree of accuracy to which their work is carried out. Science approaches truth more closely than does common knowledge. In the scientific laboratory, the worker measures dimensions with a micrometer graduated to the thousandths of a centimeter, while in contrast, in the world out-

side, the carpenter makes his measurements with a two-foot rule divided into sixteenths of an inch. While making his accurate observations, the scientific worker is careful never to intrude his own opinions, prejudices, and passions in any way that will affect the results. He tries to suspend judgment until the facts are before him.

In describing as "scientific" any method of seeking guidance which is marked by investigation, is to assign to the word a significance of wider application than ordinary. Scientific procedure is often regarded as a difficult, complicated, and mysterious method of securing and arranging facts — a method entirely different from, and alien to, the methods of crude "common sense." Such a concept of the scientific method is neither accurate nor useful. Fundamentally, the method of science *is* the method of common sense. The procedure of the learned astronomer to determine the position of some remote star differs in no essential way from that of a repair man locating a puncture in an inner tube. The differences between the methods of the professional scientist and the practical mechanic are limited to such accidental phases of their work as the complexity of their respective calculations, the elaborateness of their apparatus, and the accuracy of their observations. They use identical methods. They investigate. Neither attempts to solve his problems by consulting authorities or by guessing. Says Pearson, on this point: [1]

> The man who classifies facts of any kind whatever, who sees their mutual relationships, and describes their sequences, is applying the scientific method and is a man of science.

[1] Karl Pearson. *The Grammar of Science*, p. 12.

Robinson expresses a similar point of view when he says:[2]

> Science is by no means confined to stars, chemicals, physical forces, rocks, plants, and animals, as is often assumed. Instead, science includes all the careful and critical knowledge we have about anything.

The scientific study of any problem is the substitution of certain ways of "making sure" about it for the common and lazy habit of "taking it for granted," and for the worse habit of making irresponsible assertions about it. The classification of facts and the formation of judgments upon the basis of the facts — judgments independent of the idiosyncracies of the individual mind — essentially sum up the aims and methods of modern science. As Pearson says, "The scientific man has above all things to strive at self-elimination in his judgments, to provide an argument that is as true for each individual mind as for his own."[3] The scientific method is not peculiar to one class of phenomena or to one class of workers. It can be applied whenever and wherever there are problems to solve and facts available which bear upon the solution. In addition to extending our knowledge of the world about us, the scientific method can be profitably applied in adding to man's knowledge of himself, of his mind and how it operates, and of his social relationships and their history.

Development of the scientific method. Before the scientific method was developed, the custom was to appeal to authority for guidance. This means things were done in a certain way because they had been done that way, because

[2] James Harvey Robinson. *The Humanizing of Knowledge*, p. 57.

[3] Karl Pearson. *Op. cit.*, vol. II, p. 6.

some one who was held to be a repository of truth advised it, or because some one in power wished it. People have always wished to avoid the last: that is, being subject to individual whim, desire, and caprice; and to avoid it they have consulted sacred books, the law, oracles, or the vote of the majority. Before science, in the event that information and guidance were wanted, opinions were collected, books and documents were studied, and oracles were consulted, but never were investigations made. A teacher of medieval times was giving a lesson from Aristotle about the horse. To his consternation, he found that the page which told the number of the horse's teeth was missing. "Alas," he cried, "the page is gone; there are no more perfect copies in existence. Now we shall never know how many teeth a horse has."

The idea that authority might not be dependable was scarcely ever held. During the middle ages a monk was teaching a group of boys. He stood before them reading from the textbook of the times — Aristotle. The subject of the lesson was the lion. Among the pupils was a lad who had had the good fortune to travel in Italy. While there he visited the menagerie of Frederick II at his palace in the southern part of the peninsula, and had observed a lion. As the monk read Aristotle's description, he noted that it did not tally with what he had himself observed, so he objected to the account. The horrified monk asked: "Upon what grounds do you question the words of the great philosopher?" "Master, I have seen a lion with my own eyes," said the boy. "If you have seen a lion and he was not like Aristotle's," said the stern monk, "then the lion was mistaken."

Another method, nearly as ancient as the method of asking some one else (the method of authority) is the method of speculation. Asking is prompted by faith; speculation by doubt. In one case the answer is asked for, in the other case it is guessed at. Now science differs from both of these methods. Its chief motive is curiosity; the answer is obtained by research. Asking gives rise to religion, speculation to philosophy, and research to science. Truth cannot be divined; it cannot be guessed; it can only be discovered. The eager questioning reverence of religion and the nicely etched distinctions of philosophical theory have their own peculiar values, but it does not stand within their power to reveal fact. Whenever men trust to authority and speculation, they are placing their confidence in something other than, if not necessarily less than, truth. The relation between these three methods of answering questions may be seen in tabular form, below:

METHODS OF ANSWERING QUESTIONS

Method	Procedure	Highest Expression	Guiding Impulse
1. Of authority	Asking for the answer	Religion	Faith
2. Of speculation	Guessing at the answer	Philosophy	Doubt
3 Of science	Seeking the answer	Truth	Curiosity

The materials of science. Science has been said to consist of generalizations, such as concepts, laws, principles, and norms. These begin with objects and things which can be perceived through the senses. Examples of such objects and things are plants, animals, stones, stars, liquids, gases,

force, and the records made by man. They are concrete, tangible, objective. They prove themselves through the senses. They are called the *data, facts, observations,* or the *phenomena* of science. Out of these *data* arise *generalizations,* which have no separate independent existence. They subsist in the facts which they summarize and describe. Thus science is said to consist of *concrete materials* (facts, data), and *theoretical or abstract materials.* Cooley [4] distinguishes a third type "or intermediate kind of material, that is, *concrete objects,* which being purely theoretical, have the rank of *concrete ideas* and not of facts. Such are molecules, atoms, the ether, and the soul."

The observations out of which science is built come through the senses: hearing, taste, touch, sight, and smell. The effort is always made in scientific work to have the observations, that is the perceptions, made under conditions favorable to their accuracy and to their re-trial or verification. Scientific observations are therefore critical and analytic in character. The *theoretical factors* (principles, laws) are not derived directly, but result from reflective thinking on the observations after they have been organized. They are the essential and universal characteristics of the observations. Synthesis and comparison are important activities in this part of the process; they grow out of analysis and observation. Cooley says: [5] "Observation and analysis furnish the materials by means of which synthetic thought rears its edifice of knowledge."

Cooley gives a good illustration of the materials of science. In the organized body of knowledge called the solar system,

[4] W. F. Cooley. *Principles of Sciences,* p. 35. [5] *Op. cit.,* p. 36.

he says, the stars, sun, and earth constitute the *data* or *facts*; the concept of motion, momentum, and gravitation are the *theoretical principles*; while the ether, which is posited for the purpose of explaining the solar system's optical phenomena, belongs to the third group of the mind's construction materials — the *concrete ideas*.[6]

Steps in the scientific method. Since the scientific method is always and everywhere the same, there must exist some simple skeleton of procedure, which, if it can be distinguished, will help the investigator to work more effectively. After the direction of the investigation has been determined from the analysis of the problem, the first step is primarily one of observation, the second that of comparison, and the third that of correlating under a theory, with a capacity for predicting future events in the field being studied. This idea is expressed by Melvin, as follows:[7]

> A definite method of procedure is the *first essential* of all scientific work. Thus the essential process involves three steps: (1) the accumulation of facts or data through observation, (2) the classification of these facts, and (3) the discovery of relationships or lack of relationships between them.

Chapin enumerates four steps; namely:[8]

> *First step:* formulation of a working hypothesis of investigation.
> *Second step:* collecting and recording the facts of observation.
> *Third step:* classification of the facts of observation.
> *Fourth step:* generalization from the facts of observation.

[6] *Op. cit.*, p. 36.
[7] Bruce L. Melvin. "Methods of Social Research," p. 195.

[8] F. Stuart Chapin. "Progress in Methods of Inquiry and Research in the Social and Economic Sciences," pp. 390–91.

The *Character Education Institution* of Washington, D.C., has developed a list of suggestions from "scientists studying inanimate nature" which give and define the necessary steps in scientific research. This list is a most excellent one, and contains most of the essentials of the whole process of thesis making. The six steps follow:

1. Gather data on the problem or within a selected field according to some adequate plan, by means of numerous and accurate observations made with the human senses, assisted and corrected by instruments of precision.... Observations must be recorded in definite terms, and measurements, and in specific statements.
2. Classify data on the basis of similarities, variations, activities, processes, causes, and results. Distinguish between essential and superficial characters.
3. Generalize to get principles and theories into tentative form. Use constructive imagination, discernment, and known principles to formulate reasonable generalizations that solve the problem, or explain the known facts in the selected field.
4. Verify generalizations by controlled experiments, by tested prediction of results, by repetition of experiments, and by the gathering of additional data. Appraise data.... Determine sources of error in method and apparatus....
5. Report the research in full, and subject the results to criticism and verification by others competent to collaborate.
6. Announce the results to the general public for practical use.

Another way to show the meaning of scientific method is by stating the errors and fallacies which occasionally attend it, and which must be avoided if strict adherence to scientific method is obtained. These errors to be guarded against in every step of the process are:

1. Constant error due to the prejudice or bias of the observer;

2. Constant error due to lack of precision in the instruments used;

3. Variable error either in the observer or the instruments;

4. Errors of judgment, and illusion or false perceptions;

5. Wrong inferences;

6. General conclusions from too few observations;

7. Careless, vague, and ambiguous use of terms;

8. Errors in the mathematical manipulation of data;

9. Errors due to writing from memory, and

10. Errors in clerical and record-keeping activities.

The main steps in scientific method have already been stated as: (1) observation (collecting data), (2) classification, and (3) generalization. The three sovereign procedures to use in collecting data are the normative, the experimental, and the historical. Each of these will be described in detail in succeeding chapters. At this time, consideration will be given to principles governing the observations of which science is made, giving particular attention to their validity, reliability, and classification.

2. *Validity of observations*

The first requisite of the data, facts, phenomena, and observations is that they be *valid*. This means they must be essentially what they purport to be. All relevant facts should be collected; all irrelevant facts omitted. Observations on the life history of the fern, for example, are valid only:

1. If they contain all the pertinent data on its life history; and

2. If they do not include anything which does not belong in the life history.

Tests of validity. Validity tests invariably go back to the sources from which the data were obtained. A student in economics, let us assume, is writing a thesis on school indebtedness. The sources of his data are the annual reports of county auditors. The question then is whether the data which he has taken from these reports are the real facts of indebtedness. Do they represent all the facts? Are data included that should not be included? From what source or sources did the auditors obtain the data which they publish in their reports? Some proof of authenticity is lent to the reports by the knowledge that they are attested under oath. If still unconvinced of their validity, the next step is to go to the original transactions, as shown by records of school boards and confirmed by other evidence.

In history, validity may turn about the genuineness of documents. In natural science, it may be concerned with the time and the place of the observations. When experimental data are under consideration, the question of their validity may have to do with the degree to which controlled conditions were maintained. At all events, in any and all investigations, the most fundamental question which can be asked is, "Are the data valid?" No matter how precise the measurements may be, no matter how careful the analysis, no matter how modest the generalizations, all count for nothing if the facts themselves are untrue.

Where data are obtained through measurement, there is not only the question of the validity of the sources to be established, but the validity of the measuring instrument

as well. The validity of a measuring instrument depends upon the fidelity with which it measures what it purports to measure. Thus a measure of beauty is not a valid measure of intelligence.

A measure is valid when it agrees with a *criterion*. A valid measure of an arc is reached by measuring it with an instrument scaled in the standard of circular measure, the degree. A valid measure of length is obtained by measuring it in terms of meters, a natural standard representing one ten-millionth of the distance from the poles to the equator. Since most measures are arbitrarily assumed, the establishment of their validity is itself a problem associated with research.

The validity of a measuring instrument can be determined by checking it against other measuring instruments of known validity. Thus assume that X can be measured with instrument A, and assume that similar results can be obtained by applying instrument B to X, then B is a valid measure of X, or A has been used as a criterion by which to test B.

When like measuring instruments are not available or practicable, a criterion representing the closest possible estimates of the value of the thing being measured is applied, and the results compared with the results obtained by applying the foot-rule (the measuring instrument). To illustrate, suppose an experimenter wished to measure intelligence. He prepares his measure of intelligence (foot-rule), and applies it to the intelligence of several thousand subjects. He then has competent persons estimate the intelligence of the same subjects. These estimates are his

criterion, and, by comparing his actual measurements with the criterion, he is able to tell whether his instrument really measures intelligence or not. If the measures agree with the criterion, the assumption is he has true measures of intelligence; if they do not agree the assumption is that his instrument is invalid.

Reliability of observations. In addition to being valid, observations must be reliable. The essential test of reliability is agreement. To illustrate, suppose that observer *A* measures the height of a boy and records the result as 48 inches. Suppose he immediately repeats the same measurement, and the result is registered this time as 40 inches. Suppose the measurements are repeated by *B* who obtains successively 52 and 45 inches. Such variations warrant the conclusion that the observations are unreliable.

Another illustration may be given to clarify the concept of reliability. *A* and *B* hear the same explosion at equal distances from the source, consult accurate watches, and report independently the exact hour of the explosion. *A* reports 11:55, *B* reports 11:52 o'clock. Suppose also that neither had any other interest in the explosion than the mere wish to be as accurate in their reports as possible. By an accurate mechanical timer, a record is made which shows that the explosion actually occurred at 11:51:42 o'clock. *B*'s observation is the better and the more reliable because it comes nearer the truth.

If *B* can make such a record consistently he may be called a very reliable observer of the type of event under consideration. The degree to which his reports are reliable can be obtained accurately, but, in order to know how accurate his

observations are, there must be some outside standard of reference against which the observations may be checked. This standard may be derived by the use of a mechanical record, as in the example just given, by an observation made by another person known to be very reliable and willing to make the observation, or by an average of a series of observations made by a competent observer or by a group of competent observers.

When measurement is involved, there are two factors of reliability to consider:

1. The reliability of the measuring instrument, and

2. The care and accuracy with which the instrument is applied. If, in measuring the height of a boy, *A* used a foot-rule only eleven inches long, his results would not check with those of another observer of like care in measuring who used a twelve-inch rule. Or, in the case of timing the explosion, if *A* was two seconds slow in looking at his watch, or forgot whether his observation was 11:54 or 11:55, an error due to the observer would result. When carelessness or lack of ability in making observations are combined with the use of inaccurate instruments, the results cannot be regarded as true science.

3. *Obtaining reliability*

Reliability is obtained in four ways: (1) objectivity, (2) emphasis upon a relatively narrow and a definite field, (3) accurate enumeration and measurement, and (4) accurate and complete records. These means will next be discussed, in order.

1. *Objectivity.* By an objective observation is meant one

independent of the attitudes, prejudices, and anticipations of the observer. Such an observation will be free from what has been called "idiosyncracies of the individual mind."[9] Few observations attain a perfectly objective quality, and most of the observations of everyday life are greatly distorted by personal bias and fallibility. The rigorous application of ordinary honesty will decrease, though it will not eliminate the effects of subjectivity in observation. Diligent practice in making the observation ordinarily results in increased reliability, because it tends to make the process mechanical. Still, when every precaution has been taken, subjectivity in observation remains as one of the worst hazards in research — one of the worst because it is both difficult to detect and unpleasant to admit.

Pure research always puts a premium upon objectivity. The worker is in search of truth; he does not care what the truth is. The person who does care, who labors to add to his popularity, make a fortune, or create a sensation, undergoes constant temptation to let his desires influence his results, and to produce results that are not true. A hundred years ago, the whole science of electricity was summed up as having "no possible practical use." Without regard to whether their work was useful or not, the early research specialists studied electricity intent only upon finding the facts. They eliminated "I think," and "I believe," expressions nearly always fathered by "I wish." Their procedures and results might be checked by any one with patience and understanding to follow the process. Objectivity not only makes for reliability in first trials, but it permits of retest and verification until nearly perfect certainty is obtained.

[9] Karl Pearson. *The Grammar of Science*, vol. II, p. 6.

2. *Limiting the field.* The second requisite to reliability is emphasis upon a narrow and well-defined field. By not attempting too much the student can concentrate upon accuracy; he can do intensive work. An accurate study of the geology of northern California would tax the efforts of several workers for years, but the geology of a small area, or some aspect of it, comes within the limits of a thesis. A history of reconstruction in the South following the Civil War would occupy an energetic scholar a lifetime, but a student can make some progress in preparing his thesis with a subject bearing upon political reconstruction in one State.

Students are often indifferent to specific and narrow subjects because they feel such subjects do not offer adequate data, and do not afford sufficient scope for their powers. This is because their observations are superficial and casual. One of Agassiz's pupils asked for an assignment. The master placed a few fish of one variety before him and said, "Study these." The student persevered for an hour or so, and then feeling he had exhausted the subject asked to be assigned something else. The trained scientist then called for a summary of what had been observed, and soon was able to convince the apprentice that much more remained to be noted. In this way, the student reporting all that he had learned, and the master making suggestions that led to further discovery, the study progressed until there had been collected many facts and the student was ready to form a few tentative generalizations. Moreover, the student had developed some capacity for independent work, some skill in technique, and an attitude of persistent interest.

Analysis is the method employed in reducing the field of

investigation to elements sufficiently small for a thesis. In studying a plant, observations may first be directed to the root, next to the stem, next to the leaves, and finally to the flower and fruit. As knowledge of these grows, factors within limited fields emerge as satisfactory problems. An historical subject may be subdivided in small units of time, such as a year, a legislative session, or a political administration. Darwin confined his first observations, on reaching a new island, to the geological formations along the coast, taking later the interior areas. In studying fish, Agassiz's pupil first observed the scales and their arrangement, then the gills, and so on, following a uniform order with each specimen, and centering upon only one character at a time.

To give more specific directions for helping one to continue the study of a limited subject, until all possibilities are exhausted, is another matter. One of the best suggestions is: repeat observations frequently. Observe one individual or source many times; observe many individuals many times. Keep a record of each observation, so as to make a test of reliability possible. The next suggestion is that the student attempt to derive new observations by looking for resemblances and differences. A third suggestion is to note what the thing will do and of what it is composed.

Pride should have some influence in making a student attentive to this requisite — a narrow field, because the American student is accused of scattering his efforts and of making only surface observations. He supplies, it is said, in this respect, a marked contrast to the more refined and concentrated efforts of the European scholar. Whether this is true or not, he should realize, as Mark Twain pointed out,

the impossibility of treating the past, present, and future of the Mississippi Valley in a thirty-minute lecture.

The limits of the chosen field should be well defined. Working within definite boundaries not only prevents wandering and wasted effort, but it makes verification possible. A report that gold is plentiful in the Cascade Mountains in Oregon does not give much direction to the search, but if the location of the field is given in terms of the legal description, or in terms of latitude and longitude, the treasure may be found. Historical research may be limited by stating the dates marking the beginning and end of the period covered, and by giving the place, movement, or event. Geological research may be limited within specified boundaries; chemical research by naming the elements or compound involved; psychological research by stating the age, sex, residence, etc., of the subjects.

3. *Enumeration and measurement.* Accurate enumeration and measuring is the third requisite to reliability. Its value can be illustrated by reference to the method of Darwin, who, while not a mathematician, was a keen observer. Even before the Beagle touched her first land, he had observed that the impalpably fine dust which fell on her deck, "contained no fewer than sixty-seven distinct organic forms, two of them belonging to a species peculiar to South America." In some of the dust, he found particles of stone so big they measured, "above the thousandth of an inch square," and after noting this fact, "one need not be surprised at the diffusion of the *far lighter* and *smaller* sporules of cryptogamic plants." [10]

[10] Francis Darwin. *Life and Letters of Charles Darwin*, p. 163.

A strong temptation arises to say, "True research has not been done until one is able to say 'how many,' 'how much.'" This is a view often expressed. Mills says: [11]

> It has been well said by one of the leading physicists of the nineteenth century that when you can measure what you are speaking about and express it in numbers you know something about it, but when you cannot, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science.

Enumeration answers the question "how many"; measurement answers the question "how much." In the quotation from Darwin, enumeration is illustrated in the words, "contained no fewer than sixty-seven forms"; measurement is illustrated in the words, "above the thousandth of an inch square." Every science either uses directly or implies counting, or measurement, or both. In history, they may be generally implied. There is *one* event treated, *one* character, one event is *more* important than another. The statement of dates involves counting and measurement.

The development of instruments of precision is an essential of measurement. The invention of a reliable measuring device sometimes is used to satisfy a thesis requirement — in fact to constitute the thesis. However, it is more likely to be approved for the master's thesis than for the doctorate; it is a means to knowledge, not knowledge itself. The making of measuring devices is a likely accompaniment of research, not its end. When Copernicus made his astronomical observations, telescopes had not been invented, but he

[11] John Mills. *The Realities of Modern Science*, p. 24. The Macmillan Company.

arranged slits in the walls of his laboratory. Through these slits he could note the "transit" of the stars across the meridian. He *measured* the altitude of these stars above the horizon, at the moment of "transit," by means of a quadrant *which he devised.*

Research and the quantitative method. Although measurement is often used to signify both counting and the application of instruments of precision, it has been restricted to the latter meaning only in this volume. Research may be carried on by counting only. For example, one may collect data by counting the number of parts of a flower of a given species, or the rays of a species of shellfish. However, more data are available when the parts of the flower and the rays of the shellfish are measured, for though concepts may readily be resolved from the simple classification which follows counting, laws and principles chiefly eventuate from the examination of the data of measurement. This point is well substantiated by Cooley: [12]

> Science in its elementary stages is qualitative — concerned chiefly with the presence or absence of qualities. But as it advances, its attempts at greater precision of observation and statement oblige it to take account of things quantitatively. It has to consider the amount or dimensions of the objects before it, and their functions and constituents. This, of course, creates a need for accurate measurement, a need which is felt first and most in dealing with continuous quantity. Later it is discovered that even when quantities are discrete, adequate exactness can be attained only through measurement, since the units are never quite uniform.

The terms "discrete" and "continuous" quantity deserve explanation. Things which exist in nature in separate

[12] W. F. Cooley. *The Principles of Science*, p. 102.

units are discrete; that is, flowers, trees, animals. A simple and definite quantity derived by counting is expressed when one speaks of 100 children, 200 flowers, 150 birds, and 75 fish, but, if the quantities do not exist in natural units, they are said to be continuous. Examples of continuous quantity are such substances as water, air, land, and metals; concepts such as intelligence, leadership, and artistic ability; and forces such as inertia, gravity, and electricity.

Discrete quantities can be "measured" in natural units: that is, one can speak of so many hundred head of cattle, so many children, so many dozens of eggs. In dealing with continuous quantity, arbitrary units are usually devised: gallons, cubic feet, acres, pounds, and the like. Continuous materials cannot be counted until they have been divided up; that is to say, measured. Cooley says that the distinction between discrete and continuous almost corresponds to the divisions between the great fields of nature — the *organic* and the *inorganic*. The organic is discrete quantity; the inorganic is continuous quantity.

The first task in the measurement of continuous quantity is to find or develop a satisfactory unit. In the course of time there have been evolved such units as the erg, the dyne, the foot, the pound, the gallon, the acre, the dollar. In measuring very small quantities, the units are subdivided into smaller divisions. In this way, such units as the inch, the pint, the cent, and the pound have been developed. In measuring large quantities, the unit is multiplied with resulting larger divisions, of which the rod, the ton, the barrel, the square mile are typical. The common arithmetical tables of mensuration, which express the relation between the unit

and its divisions and multiples, lie at the foundation of much measurement.

Salient facts of quantity. Once a unit of measurement has been applied to quantity, there arises the need of expressing the results in convenient and understandable forms. Suppose, for illustration, that the height of 1000 boys has been measured, and some term is wanted to describe the data. One of the terms chosen for this purpose is the measure of *central tendency* or average. The average may be the mean, the median, or the mode. The mean is the arithmetic average, the median is the middle term in the whole distribution of measures, and the mode the term of greatest frequency. The significance of these measures and the methods of calculating them are explained in any book in statistics and are not discussed here.

Not only does a central tendency represent the best measure of a group or mass, but it is the best value to assign to repeated measurements of the same thing. To illustrate, assume that eleven measures of the length of a brass rod have been made, with the following tabulated results:

Frequency of values	Obtained values
1	16.2
1	16.0
1	15 9
2	15.8
1	15.7
3	15.6
1	15.5
1	15.4

Total measures....................	11.
Median (middle measure)...........	15.7
Mode (greatest frequency)..........	15.6
Mean (arithmetic average)..........	15.74

The probabilities are that any of these averages is a truer measure of the length of the rod than any one of the individual measures, such as 16.2, 15.4, etc.

Data are also summarized in terms that describe how the measures are distributed about a central tendency. In the preceding table, the highest measure (16.2) is .46 units above the mean; the lowest measure (15.4) is .34 units below the mean. If all such variations or deviations from the mean were similarly calculated and their average found, the result would be the average deviation of the measures from the mean. If these deviations were squared, and the square root of their sum taken, the result would be the standard deviation. The standard deviation is the usual *measure of dispersion* employed. In a normal distribution, a measure extending one standard deviation each way from the mean covers an area embracing 68 per cent of all the observations in the distribution.

All measurement is subject to error. If the errors are due to faults in the instrument used theyare *constant* in character. Scales may weigh too heavy, a meter stick may be a centimeter too short. If the amount of the error is known, a *correction* may be made by adding or subtracting the amount of the known error from the final value. Errors due to idiosyncracies in the observer are generally not constant, and are known as *variable* errors. A correction may also be made for variable errors by computing the limits within which the true measure will probably fall. The derived measure is then written and followed by the plus-minus sign and the correction: i.e., $16.7 \pm .0012$. This term is known as the probable error, defined as .6743 times the standard deviation.

The principle of correlation is also important in quantitative data. It is based upon the fact that the mean of any measure of a character of individuals chosen at random is equal to the means which would result if the mean of all the measures of this character in all individuals had been taken. Deviation from the mean of the whole population in any mean of a lesser number of individuals implies a selection, but if the selection is made on the basis of one character, selection is also made on the basis of any correlated character. If individuals are selected so as to take those that have the longest legs, the group will also include the tallest. Correlation is therefore regarded as a form of variation in which the correlation between the measures of any two characters is such that any change in the form of the measures of one character will be accompanied by a corresponding change in the other.

The value of correlation in research. The value of the use of this statistical tool may be made clear by recalling that one of the important outcomes of science is ability to predict what will happen. In natural science, prediction is usually based upon a knowledge of the sequence of cause and effect. If the experimenter knows that a magnet can be excited by an electric current, this knowledge gives him control, since he can produce the condition desired at his pleasure. In the social sciences, the relation between cause and effect is not so easy to demonstrate and control; hence, to obtain prediction and control, resort is had to correlation. The discovery, for example, that the character *m* is always associated with the character *p*, to obtain *m* one has only to select on the basis of the factor *p*.

The value of correlation may be further illustrated. Assume theoretically that the human trait called acquisitiveness can be measured easily and accurately. Assume that teaching ability is a difficult complex to measure. Assume further that, in the course of experimentation, the discovery has been made that that acquisitiveness and teaching ability are negatively correlated to a high degree. Now, since it is important to know who possesses teaching ability, the selection of teachers might be made by administering the easy test of acquisitiveness, though no one would maintain that acquisitiveness has necessarily any cause-and-effect connection with teaching ability. *Any measurable quality* or character whatsoever, correlated to a significant degree with any important character, itself becomes important because of the possibility of using the measure of the first to prophesy the second. Indeed, Pearson has gone so far as to suggest the replacement of the "conceptual figment," *causation*, with *association*, or correlation.[13]

Pearson sees the problem as follows: "If the causes have such and such a degree of likeness, how like will the effects be?" His theory is that anything which antedates or accompanies a phenomenon is a "cause," in the scientific sense. If variation of the cause produces no effect upon the phenomenon, there is complete independence of these factors, that is to say, correlation is zero. If variation of the cause produces variation in the phenomenon, then there is correlation, ranging from just more than zero to perfect correlation, which is expressed as 1.0. Variation between measures of two characters may take place in the same

[13] Karl Pearson. *The Grammar of Science*, pp. 156–57.

direction: i.e., as height increases, leg length increases; or in opposite directions: i.e., as the length of the day increases the length of the night decreases. The first is expressed as a positive term, the second as a negative term.

4. *Accurate and complete record*

The fourth essential to reliability is complete and accurate record. The choice is between record and memory. A very simple test will give proof that to trust to memory means error in the final results. How long could a business man keep track of his transactions without the aid of a bookkeeper? How long would men in business retain the relationship of debtor and creditor unless books were properly kept? In a like manner, the observations of science should be set down in a systematic and understandable manner, *at the time the observations are made.* Otherwise, there is added to the uncertainties of sense perception the uncertainties of recollection. One in search of truth cannot afford to rely upon his own memory, or upon the memory of any one else to keep his data accurately.

The great scientists have been very particular about the record of their observations. Darwin's observations made during the five-year voyage of the Beagle required eight volumes for their publication. His collections, which are also to be regarded as "records," were very extensive. Copernicus kept a full record of his observations of the motions of the planets. From these he compiled his tables of planetary motions. These tables were easily the best of his time, and remained in use long after his death. Good accounting is the best protection against error there is, and

offers the simplest and only dependable way for the verification of findings.

Classification of data. From the original record of observations, the scientist proceeds to bring together those that are alike. The necessity of this step is seen when it is recalled that science is an *organized body* of knowledge. The mere piling up of data no more makes science than the piling up of bricks makes a house. There must be form, order, coherence; the parts must be fitted together. Basically, classification includes the putting together of the like, and the giving of simple and brief terms to the like. The distinguishing characteristics of plants of the Lily family are bulbs which survive the winter, slender leaves, showy hypogynous flowers, and regularity among the parts of the perianth. The result of the classification of plants having these characteristics is the concept, *Lily*, with the scientific meaning just given.

Three important rules of classification may be given.

1. The first is: *include all the cases in the genus.* Thus, in classifying members of the Lily family, it would be an error to omit such species as hyacinth, tulip, dogtooth violet, trillium, and brodiæa or for them to have been classified as Iris, or with balsam, mallow, and nightshade.

2. The second rule is: *employ only one principle of division.* A class which included red, white, yellow, and sweet-scented flowers would violate this principle.

3. The third rule is merely a repetition of a cardinal principle of scientific method, namely: *conform to the facts observed.* If one described members of the Lily family as choripetalous, and epigynous, he would violate this rule.

Quantitative data fit in readily with accurate classification. A simple quantitative interval is the beginning place. It proceeds to larger intervals, and finally to a point where only two or three distinctions remain in the whole mass of facts. If measures of the height of boys in school range from 42 to 72 inches, thirty classes may be made, the intervals between each being only one inch. These intervals may be decreased to three with ten inches to the intervals, and the boys described as tall, average, and short. Categorical terms of this kind are frequently employed, but they have definite meaning only when back of them are valid and reliable quantities.

Summary. The scientific method is universally employed in the research process. It follows a systematic plan, beginning with hypothesis, and passing in order to the collection of facts, the classification of facts, and generalization from facts. The observations of which science is made must be valid and objective. Valid observations are authentic, true; they are what they purport to be. Reliable observations are accurate, without significant error. Validity is established by proof that the sources of the data are genuine, and, if measurement and counting are employed, that these genuine sources have been used. Reliability is dependent chiefly upon four factors: objectivity, a limited field, accurate enumeration and measurement, and careful record.

EXERCISES AND PROBLEMS

1. What was the contribution of Francis Bacon to scientific method?
2. Select one of the great scientists: Darwin, Pasteur, Faraday,

Davy, Copernicus, Galileo, Kepler, Ampère, Thomson, Lyell, Langley, Doyle, Jenner, Helmholtz, or other, and find out all you can about his method.

3. Point out from your own environment examples of discrete quantity. Continuous quantity.
4. Discuss the significance and limitations of the oft-repeated statement that anything which exists in quantity can be measured.
5. A garage mechanic locates a puncture in an inner tube. Show that he uses the scientific method.
6. Is it possible for one worker to be more scientific than another? Discuss.
7. Cite evidences of the tendency to refer to authority to-day as a means of answering questions.
8. Explain the difference between the qualitative treatment of data and the quantitative treatment.
9. Consult Jevons for information on units of measurement, and report what is found.
10. Many accounts of the voyage of Drake are based upon *The World Encompassed*, a purported journal of the expedition. The validity of this source has been found to be doubtful. What is the effect of such a conclusion upon the truth of the history which relies upon this particular source?
11. Show how the validity of a source of data differs from the validity of an instrument of precision.
12. Explain why only a narrow and sharply limited subject should be chosen for a thesis.
13. What conclusion can one reach from the story of the experience of the student and the method of Agassiz?
14. How does limiting or defining a thesis subject differ from narrowing it?
15. Read Pearson on "Correlation and Association," and some writer like Cooley on "Cause and Effect." To what extent can you reconcile their views? What are your final conclusions on the matter?

PROBLEM 5

The Progress of Scientific Knowledge

Situation 5: At a recent meeting of the Carizona scientific society, one of the members discussed the progress of science. He pointed out the great discoverers of the last two or three hundred years, naming Darwin, Helmholtz, Faraday, Pasteur, Bernard, Koch, Ehrlich, and Galton. "The scientific method is universally known in our country," he said, "and its results are universally accepted and relied upon. Ignorance and superstition are rapidly passing away. The old reliance upon authority and baseless opinion is a thing of the past. Science has brought an end to intolerance, it has increased the comforts of mankind, it has conquered disease, and freed us from the quack and the witch doctor. Its conquests only open up greater victories ahead, which are sure and certain."

Another member of the association took a different point of view. "Only a beginning has been made in educating people to the meaning of science and the technique of scientific process," he declared. "Ignorance, superstition, and intolerance abound on every hand. Not five per cent of the people of the county have the slightest conception of the purpose and method of science. Science is, itself, beset by enemies on every hand; there are plenty of people who would gladly legislate it out of existence. Even in the universities, there are persons more concerned about being confirmed in their own views than in having the truth brought to light. There are cults and quacks and nostrum peddlers in every community of any size. They have never flourished as they flourish now. Science seems at times to come to their aid, for, as new discoveries are made, something about them is seized upon to victimize the credulous. Proof is to be found in court records, in daily experiences, and in books, newspapers, and magazines. Laboratory courses do not teach true scientific method; graduate courses give little attention to instilling the meaning of true science. We, who are interested in the progress of truth, cannot rest on our laurels. The battle is on."

Problem 5–A: What proof can you submit that the last speaker is right?

Problem 5–B: What steps can be taken to add to the progress of scientific knowledge?

Special questions:

1. Is the mere fact that what is called science is taught in the schools evidence of the progress of knowledge of science and scientific method?
2. Are there societies and cults in existence which have their bases in invalid sources?
3. Are political agencies, such as legislatures, generally friendly to science?
4. Do people prefer to depend upon guessing and asking rather than upon research?

Bibliographical note: A display of common advertising matter, and even so-called news articles, would supply some evidence in line with the problem. Certain scientific and professional magazines, such as the *Journal of the American Medical Association*, are suggested. There are also several books on cults, quacks, and nostrums. Typical educational programs ought to offer some help on the second problem.

PROBLEM 6

Limiting the Field of Investigation

Situation 6: Mr. Hawkins, a graduate student in sociology at the University of Illaowa, is interested in the subject of racial relations. He has observed the influx of Orientals into the Western States, and has noticed the rising tide of feeling against this immigration. He has made brief excursions into the history of the exclusion of the Chinese, and of conditions that led up to the Gentleman's Agreement with Japan.

He wishes to find the sources of discord; to learn the real factors responsible for the demand for exclusion. "What is the cause, or what is one of the most important causes of the feeling against Orientals" is his problem, as he has conceived it.

He recognizes that he cannot follow out all the leads that might be suggested by a problem so vast in scope as this. Many assumptions have been made. It has been said that the lack of accord springs from differences in race, in religion, in standards of living

in moral standards, in food habits, in economic competition, and so on.

He wishes to know how he can limit his problem so as to bring it within the compass of a thesis.

Problem 6: Show how this problem, or a similar problem, can be limited to a relatively narrow compass.

Special questions:

1. Is it necessary for one to have specific knowledge of a subject before he can make suggestions for formulating a thesis topic?
2. Could this topic be limited by making it cover only a part of the whole period of relationship between the Orient and the United States? Could it be limited to the period before 1870?
3. Could it be limited by applying the problem to one national group only: Japan?
4. Could it be limited by making it cover only one section of the United States: California? Santa Clara County?
5. Could it be limited by studying one kind of sources only, as newspapers?

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CHAPTER IV

THE GENERALIZING PROCESS

1. *Generalization*

The value of generalization. The scientific process is not considered complete until the subject matter is organized in general form. The thesis begins with generalization and ends with generalization; that is, it goes from hypothesis to principles. Hypothesis is followed by the elementary stage known as observation, after which comes calculation, and finally correlation under theory with capacity for prediction. Darwin used to say that no one can be a good observer unless he is an active theorizer. "I am a firm believer," he declared, "that without speculation there is no good and original observation." He had reference here to that primary stage which is known as hypothesis, for generalization from data is not of the speculative type.

Ancient people, such as the Egyptians and the Babylonians, applied science in many ways, but they were negligent in generalizing *before* and *from* their observations. The beginning of generalization was left chiefly to the Greeks. One of the first principles formulated was by Thales, to the effect that all things are derived from water. One of his pupils later taught that all things are from air, while Heraclitus still later believed the fundamental principle to be fiery vapor. At a later period, Empedocles set forth the doctrine that there were four basic elements — water, air, fire, and earth; and Democritus, in his time, resolved all

matter into indivisible particles called atoms. Under the Greeks science emerged as organized knowledge; truth tested and put in order. Without the generalizing process there can be no real science.

Generalization as a guide. In thesis writing, the first need for generalization is to guide effort. To count at all, there must be direction and limits. Something is needed to tell where to begin, and what way to go. A simple illustration will make this clear. A fisher goes out on to the lake to fish. In casting his bait, he is guided by signs that to his practiced eye reveal the probability of a catch: a rocky headland here, deep water under a shelving bank there, a ripple that betrays the passing of a school at another place. If, instead of being skilled in fishing, he were a beginner, he would perhaps rely upon the advice of others. Some one would say to him: "Try your luck out by the headland," or "keep away from shoal water."

Lacking both experience and advice, assuming direct signs of fish are not evident, the only thing he can do is to try it out, casting in the deep water by the shore, then in the current off the headland, then in the ripple over the shoal. In every case, there is implied the faith that "if I fish here I shall catch fish," or "I shall find out if there are fish here"; and his behavior in principle is akin to one engaging in research. After his trial or test is over, he may be able to form some such general statement as, "The fish I want to catch are found only in shoal water," and such an assumption is easily put to the test in future expeditions.

When to generalize. Speculating and generalizing have become subjects of contempt because too many have been

satisfied with them alone. They have substituted wishes for reality. As the result of this tendency to avoid reality, two valuable suggestions have been offered to graduate students: (1) do not speculate on possibilities until action is proposed, and (2) do not generalize except on the basis of accomplishment. A person who declares, "If I fish near the headland, I shall catch fish," is under obligation to put his assumption to the test; one who declares, "Fish have always been caught about that rocky point," should have indisputable proof of his assertion.

The essence of this advice has often been expressed. Tycho Brahe said to Kepler, "Do not build up abstract speculations concerning the system of the world, but rather first lay a solid foundation in observations, and then, by ascending from them, strive to come at the causes of things." William Occam set down as a cardinal principle of science that "Theoretical existences are not to be increased without necessity." These rules, one should remember, put no limit upon the increase of facts, nor upon the use of tentative assumptions to guide one while he is collecting facts. The source of knowledge is thus left unrestricted; the warning is against that kind of idle guessing which is not followed by research and which does not grow out of research.

These injunctions are worth heeding. Primitive people nearly always drifted into the lazy method of explaining natural phenomena by attributing them to gods, ghosts, and demons. They were the prey of superstition, and at the mercy of distorted imaginations. The scholastics of the middle ages scarcely went beyond them in fact; they reveled in fantastic explanations, and engaged in discussion of ques-

tions that were barren of meaning. The early scientists were nearly as credulous as children.[1] Toward the close of the middle ages, Roger Bacon came forward with the wholesome idea that the foremost place in the mind should be given to facts as distinguished from doctrines; that is, theories about facts. With all his energy, he "called the science of his time from authorities to things, from opinions to sources, from dialectic to experience, from books to nature."[2]

Need of generalization. What, then, is the proper place of generalization in research? There is, *first*, the need of a guess, a speculation, an hypothesis to guide effort. There is, *second*, the need of generalization to describe and limit data. This is the purpose served by such statistical expressions as averages. This is the purpose served by Boyle's law. This is the purpose served by definition and by common names. There is, *third*, the need of generalization to satisfy reason. Origins and causes are useful for this purpose. To illustrate, take the generalization, "Snow lies on high mountains the year round." The question "Why?" comes to the mind. The answer is a generalization: "Snow the year round on high mountains results from the rapid radiation of heat in thin atmospheres." Such explanations of all observed phenomena are demanded to satisfy the reason.

There is, *fourth*, the need of generalization to make prediction possible. This is regarded as the supreme aim of

[1] Note Clerk-Maxwell's demon-sorting molecules. Henri Poincaré, *Science and Hypothesis*, p. 179.

[2] W. F. Cooley. *Principles of Science*, p. 45.

science, because, within limits, the ability to predict means the ability to control or to adapt. In the Santa Clara Valley, in California, farmers are warned when freezing temperatures may be expected in the spring, and they light their smudge-pots in time to protect the fruit. The ability of the weather bureau to predict frosts enables the farmers to save their crops. Knowing that the altitude of a mountain is 12,000 feet, a person acquainted with the principle of radiant energy can predict that it is covered with snow. However, inductive investigations do not terminate in predictions, but in generalizations called laws and principles. Prediction is made from laws and principles by a deductive process.

The basis of generalization. The bases of generalizations differ, and represent three kinds of sources.

1. *Wishes.* Those generalizations unattended by research usually arise as wishes. This is what is meant by saying that the wish is father to the thought. One wishes to catch fish; therefore, he assumes that a certain lake is good fishing ground. He wishes a certain party to be right; therefore, he assumes the motives of the leaders were proper. He wishes that income and intelligence be positively correlated; therefore, he assumes such correlation. He wishes the elementary school to have had its origin in the Reformation; therefore, he postulates such origin. Herein is the danger of fanciful speculation, which, being unproved becomes prejudice, and, in the course of time, comes to have all the force of truth. It is a good rule to avoid generalizations having their source in wishes.

2. *Data.* A second source of generalizations is data. The

data may be of the kind which result from uncritical experience, as when one observes that leaves usually fall after frosts, or that plants will not live without water. If pushed for proof of an assertion that plants will not live without water, the recourse usually is to single experiences. One says: "I forgot to water my pansies, and they died," or "While we were away on vacation last summer, our lawn died because it was not watered." Many common-sense principles have been arrived at in this way, and, since the experience of others does not conflict with *our* generalization, it is accepted as truth.

In research, this common-sense method is carried farther to include more and more accurately made observations. The investigator then generalizes from his data; usually he is not warranted in letting his generalizations have wider application than the sources from which his facts were derived. If he has examined a thousand trees, he can report that "all the trees of the varieties included in his study in this locality shed their leaves after frosts." If he knows the general principle of the uniformity of nature, he may generalize that "all trees of this locality of the varieties observed" shed their leaves after frosts, but he would not be entitled to generalize that all trees of whatever species in all climates shed their leaves after frosts. Generalizations on the basis of single experiences or single arrays of facts are said to be *empirical*. Their applications are limited to the data upon which they are based and to data of the same kind and extent.

3. *Comparison of generalizations.* A third source of generalization is comparison of generalizations derived from

facts. Darwin generalized from this source. He collected facts and summarized them. He compared his generalizations with generalizations reached by the geologist, Lyell, and by the sociologist, Malthus. From generalizations on the struggle for existence and the survival of the fittest, he passed to a consideration of the origin of the species and from thence to the theory of evolution. Murray says:[3] "Collection and observation had given him one half the subject matter of the *Origin of the Species*. It was reserved for reflection and Malthus to give him the other half." Universal principles result in this way.

2. *Types of generalization*

The three types. The three types of generalization which have been described are known as: (1) hypothesis and postulate, (2) norm and law, and (3) theory. Collectively they are known as principles, though more properly norm and law are thus known, since they are based upon facts directly. To a limited degree, the arrangement of hypothesis, law, and theory signify an ascending order. Science, some one has said, has its germ in hypothesis, is married by research to law, and gives rise to theory. A norm and a law subsume the hypothesis from which they each arise. A theory is a broader, more general term than hypothesis or law. It is often regarded as a generalization of hypotheses; it should, however, spring from law.

1. *The hypothesis*. The hypothesis is used in this discussion to signify a general statement formulated on admittedly insufficient data for the purpose of establishing a sufficient

[3] R. H. Murray. *Science and Scientists in the Nineteenth Century*, p. 176.

degree of order and direction to permit the investigator to proceed. The word comes from the Greek *hypo* = under, and *tithemi* = place. Referring to science, its dictionary definition is "a comprehensive tentative explanation of certain phenomena, which is meant to include all other facts of the same class, and to bring all of the related facts into comparison; if the hypothesis explains all the facts, it is regarded as verified; till then it is regarded as a *working* hypothesis." In this sense, its meaning is the same as postulate.

Originally, hypothesis was a working assumption adopted as a means of explanation. As Mill says, "It is any supposition made in order to deduce conclusions in accordance with facts which are known to be real." Postulate also originally meant a preliminary assumption leading to deduction from real facts. The tendency now is to use hypothesis to assert something to be true (without proof); to use postulate to assert (without proof) that something can be done. The basal principles of science were originally hypotheses; of invention were originally postulates. As Cooley says, they are readily accepted because they are necessary starting points of science and the progressive control of nature, and they naturally lead to their own justification (or rejection).[4] Any assumption or assertion not followed by research has the status of opinion, guess, and belief.

Science and hypothesis. Many examples of hypothesis may be found in the history of science. Jenner stated that "cow-pox protects the human constitution from the infection of small-pox." He obtained this *hypothesis* from a

[4] *Op. cit.*, p. 198.

dairy maid, who, when he mentioned small-pox to her, said, "I cannot take that disease, for I have had cow-pox." The double-fluid hypothesis declares that electricity consists of two tenuous and imponderable fluids, one positive, the other negative. The filiar hypothesis is the assumption that protoplasm consists essentially of separate threads. Olber's hypothesis explains asteroids as fragments from the explosion of some primordial planet.

Writers sometimes declare that all science is hypothetical. By this they mean that absolute and final proof of assumptions have not been made, and cannot be made.[5] The movements of the planets, which seem to follow immutable laws, may perhaps be changed in the future by the intervention of an unknown body or by the disintegration of a known body. A new discovery in one field may bring about a revision of the principles of another. The chief values of acknowledging the hypothetical character of science are two: (1) to keep from being cock-sure and dogmatic, and (2) to keep an open mind ready to receive truth whenever it is presented. The questioning, inquiring, tentative attitude is characteristic of the scientific spirit.

The fact that a scientist accepts the view that all science is hypothetical does not keep him from acting on the basis of the facts he has. By his way of thinking, all hypotheses are working hypotheses. He goes ahead and uses them with discrimination, but rejects or revises any as a basis of action when facts seem to warrant the change. His chief criterion

[5] J. W. N. Sullivan, in *Aspects of Science*, p. 18, asks: "If the scientific method is infallible, why are the results reached by it provisional? To judge from the history of science, the scientific method is excellent as a means of obtaining plausible conclusions which are always wrong."

of truth becomes, "Will it work in the situation and under the conditions with which I am confronted?" So long as it works, he accepts it as truth.

Hypotheses might easily be classified if there were any value in so doing. One which asserts the truth of a general idea: that is, the existence of a characteristic common to many individual cases, is a hypothetical *concept*. One which asserts the truth of a general statement or a conditional event is an hypothetical *law*. One which asserts general practice or relative values (one thing is better than another) is an hypothetical *norm*.

The thesis and hypothesis. The statement has already been made that an hypothesis is necessary to research. Therefore, it is necessary to thesis making. Going back to the definition that a thesis is a proposition to be proved, obviously the thesis in its initial stage is an hypothesis. It is a tentative solution of the problem. Without some kind of assumption, research would be random, hit-or-miss, futile. To avoid direct assertion, the hypothesis may be put in question form. Jenner's hypothesis might have been expressed: "Does cow-pox protect against infection from small-pox?"

Occasionally a student is reluctant to accept an hypothesis because to do so seems like a commitment or prejudgment when the mind should be kept free for the observation of facts and the detection of clues. Francis Bacon declared, "Men should bid themselves for a while renounce conceptions and begin to make acquaintance with things themselves." In contrast with this view, there is the modern opinion of Lankester, who says:

Nature gives no reply to a general inquiry; she must be interrogated by questions which already contain the answer she is to give; in other words, the observer can only observe that which he is led by hypothesis to look for.

From the time of Darwin, scientists have usually rejected the extreme position of Bacon, and have tended to follow lines of inquiry marked out by hypotheses. The reaction against the Baconian doctrine was well expressed by Darwin:[6]

About thirty years ago there was much talk that a geologist ought to observe and not theorize; and I well remember some one saying at this rate a man might as well go into a gravel pit and count the pebbles and describe the colors. How odd it is that one should not see that all observation must be for or against some view if it is to be of any service.

The good hypothesis. A good hypothesis is one that can most probably be verified. Jevons states three criteria for a good hypothesis:[7]

1. A good hypothesis must allow of the application of deductive reasoning and the inference of consequences capable of comparison with the results of observation;

2. A good hypothesis must not conflict with any laws of nature which we hold to be true; and

3. In a good hypothesis, the consequences inferred must agree with the facts of observation.

The first two of these suggestions apply to the hypothesis before research is completed; the third may be applied as a check after the research is completed. Number one means

[6] Quoted from Allen Johnson. *The Historian and Historical Evidence*, p. 157.

[7] W. S. Jevons. *Principles of Science*, pp. 510–13.

that there must be a strong probability that a general principle will result from the research. Number two states that the probability that the hypothesis is true must hold at least to the extent that it does not conflict with what is already *known* (*known* means established by previous research). Number three signifies that if the facts do not agree with the hypothesis advanced, then the hypothesis must be revised to fit the facts. All three go back to the original statement that "the good hypothesis must be verifiable."

Verification of the hypothesis. If the question is asked, "How can the hypothesis be verified?" the answer is "By collecting observations, and classifying and interpreting them." If the facts support the hypothesis, the hypothesis is true. Jenner published his hypothesis concerning the prevention of small-pox after a study of only twenty-seven cases. Other investigators failed to substantiate his conclusions, and a warm controversy raged over their truth, humiliating to Jenner and not particularly conducive to the development of the scientific spirit. Verification means that due care has been taken to establish the truth; the facts are adequate and representative.

The question invariably asked at this juncture is, "When are facts adequate?" There is no absolute answer. The general rule is to add observations until all possibilities of error have been exhausted, or until a point is reached where the addition of more facts does not add to the probable truth of the hypothesis. (See Chapter VII.) Often conditions are such that only a few tests are needed to verify an assumption. Galileo believed that if a one-pound weight

were cast from a height at the same instant that a five-pound weight was likewise cast, the lighter weight would reach the earth simultaneously with the heavier weight. His hypothesis was that falling bodies pass through space at the same rate, irrespective of weight. He climbed to the top of the leaning tower of Pisa and performed the experiment. There was no need of many observations on this phenomenon to convince that the law of falling bodies is irrefutable.

The result of verification. The result of verifying an hypothesis is a norm, a law, or history for each of which (history summarized) the single term *principle* is used. A principle summarizes research. An hypothesis cannot result in more than one principle. A principle is verifiable by *application*; is knowledge, science, truth. Principles are the true body of science, of which data or facts are only cells. They must meet the ultimate criteria of truth, which have been expressed as: "Will it work? Can I trust my life to it?"

Gore[8] quotes Archbishop Thompson as saying:

Four principal criteria of truth have been in different forms advocated by logicians: viz:

1. *The principle of contradiction.* The same attribute cannot at the same time be affirmed and denied of the same subject, or, the same subject cannot have two contradictory attributes.
2. *The principle of identity.* Conceptions which agree can be affirmed of the same subject at the same time. This principle is the complement of the former.
3. *The principle of the middle being excluded.* Either a given judgment must be true or its contradictory; there is no middle ground.

[8] George Gore. *The Art of Scientific Discovery*, pp. 153–54.

4. *The principle of sufficient reason.* Whatever exists or is true must have a sufficient reason why the thing or proposition should be as it is, and not otherwise.

Discussing these principles, the writer says:[9]

The *first* is a caution against receiving into our notion of a subject any attribute that is irreconcilable with some other, already proved upon evidence which we cannot doubt. The *second* is a permission to receive attributes that are not mutually opposed, or a hint to seek for such only. The *third* would compel us to reconsider the evidence of any proposition, when other evidence threatened to compel us to accept its contradictory. The *fourth* commands that we seek the causes and laws that have determined the existence of our subject, for the subject cannot be adequately known except in these.

The meaning of law. If principles are the objectives of research and literally constitute the thesis, their meaning should be known. At this time, definitions will be given of law, norm, and theory, and later on (in Chapters V and VI) explanation will be given of the specific process of deriving laws and norms. As has been said, the process of arriving at a theory is chiefly deductive, and, as such, is not a prime object of thesis making; it will, hence, be treated only once in this chapter and that briefly. We turn first to the meaning of law.

A law is a principle asserting an invariable association. A cause and an effect are invariably associated; a statement of their invariable association is a law. A variable and its concomitant are invariably associated; a statement of their invariable association is a law. An example of the law of cause and effect is oxidation as a cause and heat as an effect.

[9] George Gore. *Op. cit.*, pp. 154–55.

An example of the law of correlation is the variable, height, and its concomitant, long-leggedness.

Cause and effect may quite properly be regarded as a type of association or correlation, since the relation between the cause and the effect is simply one of invariable sequence. The statement that A causes B means that A invariably goes before B. A generalization is rightly dignified by the imposing name of *law* only when it has been arrived at by deliberate and conscious investigation, and when it gives the means of predicting future events to those familiar with the phenomena and the techniques which the law subsumes. A person knowing the correlation between scores made on reliable tests M and P, and having given an individual's score on test M but not on test P, can predict his score on P. The correlation, however, constitutes the law.

The term *law* is often used somewhat loosely. It is said Newton discovered the *law of universal gravitation*, and Darwin the *law of natural selection*, but there is a vast difference in the accuracy with which the two *laws* may be used to forecast future events. The law of gravitation is true when applied to every particular instance; the law of natural selection is true in the long run. There is no way of making a distinction that will always hold between the value of positive laws and general laws, but the aim of thesis research should be positive laws.

A law also has been defined as *empirical* when its truth is not known to go beyond the data to which it owes its origin. Its meaning depends too upon its connection with other laws, and with its being true of all identical phenomena. The fact that water always rose in pumps was for many

years a well-known law, with all the elements of universality but one. That was the *why*. When Torricelli discovered that the rise of water in pumps was due to atmospheric pressure, its meaning and limits were defined, and the empirical principle became a universal law.

Thesis research seldom goes beyond the establishment of an empirical law. Further research may show it to be universal, but it is safer not to claim too much. One may, through a comparison of his own research results with the results of many other investigators in the same field, arrive at a universal law. To illustrate, there is an empirical law that gases will permeate membranes, but the *why* is unknown. It is known that an alloy is harder than the metals which compose it, that compounds containing a high proportion of nitrogen are poisonous, and that some substances do not expand with heat. To connect one's own research with unexplained principles and reach a universal law is a *desideratum* of thesis research.

The meaning of norm. Norm signifies literally *that which is the rule.* If the heights of all adults were measured (or representative sampling taken), that measure which is the median could be taken as the norm of adult height, and the heights of individuals could be compared with the norm. With data distributed on a scale, running from low to high, poor to good, inferior to superior, etc., we have standards of value, with the midpoint on the scale representing the norm. A high standard is one above the norm: i.e. the ninetieth percentile. A low standard is one on the lower part of the scale. These meanings are seen to be relative, not absolute. There is no norm which stands for ultimate truth: i.e. a

norm of intelligence, for any norm of intelligence is subject to revision as more subjects are measured and as selection breeds in or out the inferior. The concept *norm* is, however, invariable: the central tendency (usually the median) of the whole or of a representative population.

A norm often leads to a law. In correlations, the variations from norms (means) of two distributions are used as the basis of calculations. The fact that a unit of change in one variable is accompanied by a constant change in the other makes prediction possible. If the relationship between height and weight is such that every change in a unit of height, say an inch, is accompanied by a change in weight, say two pounds, having given the height the weight can be estimated, and progressive changes in weight as the height increases can also be shown. The relationship is really a law, based upon established norms. Ratios, indexes, and quotients have a similar significance.

The meaning of theory. On top of the two types of generalizations just defined — laws and norms — comes the theory. This term is used with varied meanings: *first,* to signify an assumption of an inclusive nature, stated without proof — that is, a speculation unsupported by scientific facts. In this sense, theory carries the connotation of impractical, of doubtful value, as when a person is said to be theoretical and visionary, in contrast with one who is practical, matter-of-fact, and executive.

Second, theory signifies a broad and inclusive generalization based upon scientifically derived facts and principles. It arises from the foundation of induction in the same way that laws and norms arise, but has a more general signifi-

cance. One starts with an hypothesis that a ray of light *is* such and such a thing, or *behaves* in such and such a way; he next forms a judgment that all the thousands of rays of light he has examined *are* or *behave* in the way he assumed. He derives next a universal law of light rays. The last step is a theory of light, explaining and comprising all that has been discovered about light. The order is: (1) hypothesis, (2) empirical law, (3) universal law, and (4) theory.

Illustrations of theory. Illustrations of theory abound. The undulatory theory of light is adequate to explain or comprehend the laws of reflection, refraction, and the spectrum. The theory of heat is sufficient to explain radiation and conduction. The molecular theory includes every known law of mass and composition. The theory of evolution maintains that all forms of life have their source in a common ancestry, and that species merge into one another by nearly imperceptible degrees; it embraces all principles giving the relationships among the great variety of living forms. Looked at in this way, scientific theory is the highest and most universal form of truth.

Reflective thinking is associated with theorizing, as when the worker tries to establish the relationship between a derived principle and other principles already embraced in a theory. Likewise, a theory may function like an hypothesis. Darwin's letters from South America contained mostly geological references, for even then he had begun to think of his theory of the formation of coral reefs, because of what he had observed of the extension and gradual changes in the geology of the continent. He says:

No other work of mine was begun in so deductive a spirit as this;

for the whole *theory* was thought out on the west coast of South America before I had seen a true coral reef. I had, therefore, only to *verify and extend* my views of a *careful examination* of coral reefs.

Until a theory has been well reënforced by facts and principles, it has no claim to the title, "scientific."

A theory may be entirely untrue without in any way invalidating the truth of the facts and principles used as supporting evidence. The laws of refraction will not be changed should it be proved that the undulatory theory of light is in error. A theory is merely the simplest and best explanation that can be made for the facts and laws available; and increase in the data may lead to a change in the theory. The Ptolemaic theory of the universe was supplanted by the Copernican; the emission theory of light proposed by Newton was replaced by the wave theory of Huyghen's. Legislative action can have no effect upon the truth of a theory; facts cannot be vetoed. There is no need of lamenting because the past is strewn with the bones of dead theories; their destruction was by new data, and this led to the progress of truth.

Theory and thesis making. There are at least three ways in which theory is related to thesis making. In the first place, knowledge of the underlying theory, to which the thesis generalization is related, aids the writer in understanding his own process and his own results, and helps him to make them clear to others. In the second place, knowledge of the basic theory acts as a check upon results, for if the results differ widely from, or contradict the accepted theory, the results may be called into question. In the

third place, a theory as distinct from an hypothesis may be the starting point for a definite piece of research.

Theories are most often used to explain the meaning of research results. Explanation, in general, consists in the statement of cause and of association, which is to say, the results r are caused by or associated with t. The assumption is that the meaning of t is understood. If t is unknown, there arises the necessity of explaining t in terms of the known, k. The process is identical, first, with the resolution of difficulty, the difficulty being r, and second, with the bringing both under a broader principle.

The final suggestion growing out of this chapter is to impress the worker, as strongly as is possible, with the need of familiarity with the theories in the field of his research. One should continually ask himself, "Why?" He should be able to judge his findings to determine whether they are in accord with the established theories of his science, and he should be able to judge whether new and proposed theories are founded upon research or whether they are baseless speculations. Not that contempt for speculation is necessarily an admirable trait, but ability to keep speculation in its proper place as the possible beginning of research is admirable.

In closing this chapter, there is probably no better summary of the central theme than is contained in Descartes' rules for guiding the reason in the quest of truth:[10]

Never to accept anything as true, which we do not clearly know to be so; that is to say, carefully to avoid haste or prejudice, and

[10] Quoted from W. S. Jevons, *Elementary Lessons in Logic*, p. 116. Copyright, 1901, by The Macmillan Company.

to comprise nothing more in our judgments than what presents itself so clearly and distinctly to the mind that we cannot have any room to doubt it.

To divide each difficulty we examine into as many parts as possible, or as may be required for resolving it.

To conduct our thoughts in an orderly manner, commencing with the most simple and easily known objects, in order to ascend by degrees to the most complex.

To make in every case, enumerations so complete, and reviews so wide, that we may be sure of omitting nothing.

QUESTIONS AND EXERCISES

1. Examine a thesis and see if you can formulate the writer's hypothesis. Can his results be classified as concept, law, norm, history? Discuss.
2. Select any subject which has possible thesis values, and from it formulate an hypothesis.
3. Distinguish between hypothesis and law. Between hypothesis and theory.
4. A theory has been formed upon the basis of three laws and their supporting data. How would the overthrow of the theory be brought about?
5. Examine a thesis and decide whether it should be catalogued as empirical or true science. What is the difference between the two?
6. Give the origin of the term "theory." In what different ways is it used?
7. Distinguish between scientific theory and speculative theory.
8. Why is one usually advised not to multiply theories? Does this mean that scientists advise against generalizing from laws? Explain.
9. Try to find an example of generalization which has a wish as its source.
10. Can one prepare a thesis without previously forming an hypothesis? In what sense are the thesis and the hypothesis identical?

11. Can more than one concept, law, or norm originate from a single hypothesis? Discuss.
12. Assuming that people disagree with the theory of evolution, does this disagreement have the effect of nullifying the facts and principles upon which the theory is based? Explain.
13. Is a thesis writer under any obligation to formulate a theory as a result of his research activity? To know the theory under which his generalization comes? Discuss.
14. Show what is meant by the statement that all science is hypothetical?
15. Can a theory be verified? Discuss.

PROBLEM 7

Investigating versus Theorizing

Situation 7: Two of the students at the University of Carizona are in marked contrast in their points of view. Robert is ultra-scientific. He claims that he resolved at an early age never to accept the views of other men without verification. He refused to memorize a poem assigned him in the primary school, because, as he told the teacher, he would not use literally the words of others.

He is enrolled in the department of natural science, and has a fair mastery of the technique of the laboratory. He refuses to read secondary sources, but he does read scientific notes and journals. He has not succeeded well in independent work, because he is extremely cautious, according to his instructor. He never advances an hypothesis, he knows little or nothing about the history and theory of his field. He is very precise, and spends much time getting ready to investigate. He went on an expedition to the islands of the South Seas, but returned before it was half over because he could not get along with the head of the expedition. He ponders over his own ills a good deal.

Frederick gives most of his time to speculating. He disagrees with nearly every proposition ever advanced or established. He prefaces most of his remarks with "I feel," "I believe," "I think," as if the self-reference was itself sufficient to establish truth. When he wants to utterly rout his opponent in an argument he

quotes some philosopher, or goes through a process of syllogistic reasoning in which his views are sustained in the conclusion. He claims to abhor statistics, and professes contempt for any one engaged in the laborious and undignified process of research, as he says, "finding out more and more about the less and less." Some of his theories are very fantastic; he has very little specific knowledge. He avoids contact with reality as much as possible.

The members of the departments in which these young men are enrolled are concerned about them. They wish both would secure a better balanced outlook.

Problem 7–A: What can Robert's department teach him that will give him a better balanced outlook?

Problem 7–B: What can Frederick be taught about science and how that will help him?

Special questions:

1. What is the probable source of the wrong ideas these young men have acquired?
2. What kind of authority is the scientist willing to accept?
3. Can truth be discovered through a reasoning process?
4. Is there anything in the idea some hold that to be a scientist or a scholar one has to be queer? That he has to be positive in his views?

Bibliographical note: These young men both seem to need to know the meaning of true knowledge. An insight into this can be obtained from the Selected References at the end of this chapter and from a consideration of the lives of great scientists.

PROBLEM 8

The Deductive Method and the Thesis Requirement

Situation 8: Mr. Roberts is a graduate student at the University of Illaowa. He has read the thesis requirement to the effect that it can be satisfied only by presenting, in organized form, the result of research. He is not certain just what is meant by the statement.

His difficulty arises from a number of causes. In the first

place, he is not clear as to the difference between pure research and applied research. He has the idea that applied research is research in which the results are put to immediate use in connection with life situations. If this is true, he cannot understand why any one should object to it, or why pure research should be by many regarded as superior.

A second difficulty arises from a confusion in his mind as to the difference between induction and deduction. His opinion is that induction is the process which passes from many particular facts which he has collected or found to a generalization that embraces the salient elements in the facts; his opinion is that by deduction is meant the process by which one proceeds from the generalization out to particular facts which can be comprised under the generalization. He wonders whether applied research and deduction are really one and the same.

One reason for his concern arises out of the fact that he has proposed the following topic for his thesis· namely, "The intelligence of pupils entering school for the first time." His plan is to give an individual intelligence test to a large number of beginners (representative of the whole group), and to classify the results. Pupils homogeneous in respect to intelligence would then be put into the same groups for instruction.

He is not sure, however, that what he proposes to do is research. The special questions that arise are: (1) Is this an example of applied research? (2) Is it deductive rather than inductive?

Problem 8: Make clear the distinction between pure and applied research, and induction and deduction, and show whether or not Mr. Roberts's topic is acceptable or not.

Bibliographical note: For induction and deduction see any book in logic or scientific method: for example, A. E. Avey, P. Coffey, W. F. Cooley, W. S. Jevons, W. C. Trow, and F. W. Westaway, in the Selected References at end of this chapter. For the distinction between pure and applied research see:

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CHAPTER V

THE NORMATIVE METHOD

1. *The normative sciences*

Distinguishing characteristics. The practical man is inclined to ridicule the "scientist" hunting bugs, pecking rocks, feeding worms, and pouring liquid from one beaker into another. It is only when science makes some discovery of a new machine or new force, or answers the social question, "What is best?" that he understands what science is doing. He appreciates the value of knowing "What is best?" but he seldom realizes that determining what is best is a real science in itself — the so-called normative science with which this chapter will be concerned.

Back of the question, "What is best?" is usually the question, "What is best to do?" Once the decision has been reached as to what is best, action is likely to follow, and this action may affect the welfare of the nation or of the world. Even if the question is, "What is best to believe?" there is back of the answer all the possibilities of belief translated into action, of which crusades and religious wars are examples. Often, too, conditions are such that if the question, "What is best to do?" is not answered scientifically, opinion, prejudice, and guess determine the course action takes. In the school, the state, the church, and business, necessity presses for decision, and if facts and principles are lacking or inadequate, there is no other basis than impulse, self-interest, and individual experience. The blind cannot be criticized for not walking in a straight line.

The normative sciences may be distinguished, therefore, by two chief characteristics:

1. The data and principles apply to values, and

2. There is imminent the probability of applying the facts and principles to affect life situations. The results tend to affect government, education, religion, industry, and the family; they may be used in the development of forestry, the protection of wild animals, the irrigation of arid lands, the drainage of swamps, the opening of waterways, plant and animal breeding, the control of insect pests, and the scores of other features of modern social life. In the academic field, the normative sciences include law, medicine, economics, engineering, education, art, and political science — in fact the applied and technical subjects.

The contention cannot be substantiated that any particular group of subjects or any particular field is wholly a normative science. Most of the fields which have been mentioned can also be termed *derivative* sciences, in that they or some of their branches have their foundation in physics, chemistry, sociology, or biology. Medicine is partly biology and chemistry; engineering is partly physics, chemistry, and mathematics. Education contains a subject called *Child Growth and Development*, which is biology; *Educational Statistics*, which is mathematics; *Educational Psychology*, which is psychology; *School Hygiene*, which is biology, chemistry, and physics; and *History of Education*, which is history.

Progress in normative science. On the whole, less progress has been made in the establishment of norms than in formulating natural laws. Authority and tradition have

been the guides; the doctor cited Galen and Esculapius; the teacher placed his reliance in Plato and Quintilian. The artist and the architect drew their inspiration and their ideas from Greek and Roman models. The political scientist obtained guidance from Roman towns, Greek city-states and English parliaments. Law has been and still is largely a matter of following past practices, with norms expressed not mathematically, but in the antiquated jargon of court decisions. Science promises the only means of escape from the bondage of tradition and the shackles of authority.

Problems are everywhere awaiting the research enthusiast. The enumeration of a few, in a general way, will call up many. To illustrate, there is the problem of Mexican immigration, the bicameral legislature, the reorganization of state government, the reorganization of political parties, the nationalization of education, farm relief, flood control, protection against quackery, the financing of road building, the control of disease, the prevention of poverty, and the development of honesty in advertising.

How strange it is that, for centuries, men should have neglected getting at the truth as a guide for their own affairs. The tariff has been a political issue for over a hundred years in America, but there is little or no scientific evidence as to its value, and the limits of its value. Prohibition is a question for scientists, not for politicians. Normative science cannot be said to have made much progress, since people still trust their fortunes to gamblers and dream-interpreters, their bodies to quacks and charlatans, their security to politicians, their education to disciples of Plato and Erasmus, and their souls to prophets and fundamental-

ists. Probably more people trust in the ouija board and in crystal gazing for guidance than in science. Mental healing, telepathy, and relics of saints have more devotees than the facts of a century. With such conditions prevailing, there is no doubt of the need of a new spirit of scientific inquiry in the normative sciences.

How norms are established. The study of *present practice*, of *things as they are*, is the first step in arriving at a norm. A few years ago Professor Terman, of Stanford University, undertook to discover the norm of general intelligence for American children. He collected ninety items or test problems, ranging in difficulty from tests passed by the average child of three years to tests difficult enough to try the powers of the superior adult. Included among the items were tests of memory, language comprehension, size of vocabulary, orientation in time and space, eye-hand coördinations, knowledge of familiar things, judgment, ability to find likenesses and differences between common objects, arithmetical reasoning, resourcefulness and ingenuity in dealing with difficult practical situations, ability to detect absurdities, apperception, speed and richness of association of ideas, the power to combine the dissected parts of a form board or group of ideas into a unitary whole, the capacity to generalize from particulars, and the ability to deduce a rule from connected facts.[1]

The items were next arranged in approximate order of difficulty, and submitted to 1700 children and 400 adults as tests. Their responses to each situation were recorded and

[1] Lewis M. Terman. *The Intelligence of School Children*, pp 2–3. Houghton Mifflin Company.

judged as *right* or *wrong*, a right answer carrying with it progress up the mental scale. A test passed successfully by seventy-five per cent of the subjects was considered of proper difficulty for the age: that is, if seventy-five per cent of the eight-year-olds passed a given test item, that item was assumed to be of eight-year-old difficulty. After the preliminary trial, the order of the items was rearranged from the least difficult to the most difficult, as determined by the responses of the 2100 subjects.

The results of giving the tests to a subject were called mental age. A pupil who passed the six-, seven-, eight-, and nine-year-old tests, but not the ten-year-old tests, was said to have a mental age of nine years. The ratio between mental age and chronological age was calculated, and this was recorded as intelligence quotient, or I.Q. A subject whose mental age was ten years and whose chronological age was ten years had an intelligence quotient of 100. Since the probable error of this measurement is 7, the norm is 100 ± 7; that is, it lies between 93 and 107. The range from 93 to 107 included 50 per cent of all the subjects. The distribution of I.Q.'s on a percentile scale was arranged in such a way as to show the proportion above or below a given point on the scale. The results were as follows: [2]

The	lowest	1%	go	to	70	or	below,	the	highest	1%	reach	130	or	above
"	"	2%	"	"	73	"	"	"	"	2%	"	128	"	"
"	"	3%	"	"	76	"	"	"	"	3%	"	125	"	"
"	"	5%	"	"	78	"	"	"	"	5%	"	122	"	"
"	"	10%	"	"	85	"	"	"	"	10%	"	116	"	"
"	"	15%	"	"	88	"	"	"	"	15%	"	113	"	"
"	"	20%	"	"	91	"	"	"	"	20%	"	110	"	"
"	"	25%	"	"	92	"	"	"	"	25%	"	108	"	"

[2] Lewis M. Terman. *The Intelligence of School Children*, p. 8. Houghton Mifflin Company.

In addition to the norm (the median), the table contained other standards. A subject whose I.Q. is 130 or more ranks with the highest 1 per cent; one whose score is 70 or below ranks with the lowest 1 per cent. The lower quartile is 92; the upper quartile is 108.

Validity and reliability. How does one know, one may ask, that this device tests intelligence? To answer this question, Professor Terman asked the teachers of the children tested to rate them on intelligence; that is to say, he used teacher judgment as a *criterion*. The degree of agreement between the judgment of the teachers and the results of the test revealed the *validity* of the test. Likewise, the test results were matched against the grades made in school, and with school progress. Later comparisons with these criteria and with other criteria, particularly with other tests, have demonstrated the validity of the test.

Granting that the test has validity, does it possess *reliability?* This question has been answered by successive retests of the same subject over an interval of time, by successive tests of the same subjects by different individuals, and by correlating the results obtained on chance halves of the test. Agreement in the results obtained by these methods is evidence that the test measures accurately what it does measure. The first findings have been verified by numerous appeals to experience.

Norms may be expressed qualitatively. The expression, "He is up to average," shows how the central tendency is accepted popularly as the norm. Likewise, any place on a scale may be expressed in qualitative terms. Subjects may be rated as low, inferior, high, superior, etc. Norms may be

empirical or general. The general intelligence norm is 100, but the norm for a special group may be 125. Usually, however, instead of saying the norm for this special group is 125, the percentage exceeding a given number is expressed.

Norm and law. A norm may serve to set the stage for correlation and experiment, from which laws may be derived. The practice is to locate grocery stores in closely built-up areas in the city. Ground rent is cheaper and parking space is more abundant in residence areas. The question, "Which is the better location for grocery stores?" may be answered by measuring the net business transacted in comparable grocery stores in which such factors of difference as capital, distance from homes, and prices are known and can be allowed for; that is, a controlled experiment may be conducted. Again; the practice is to devote about sixty per cent of the entire school budget to teachers' salaries; an experiment might reveal that it is better to devote eighty per cent of the total budget to teachers' salaries; *better* being expressed in measurable changes in children.

From studies of intelligence and school progress, laws such as *A subject who makes less than* 120 *on an intelligence test cannot succeed in college,* as colleges are now organized; and *a subject who makes less than* 70 *cannot graduate from high school,* as high schools are now organized, might be derived. Out of these principles grow administrative policies such as, *Do not recommend for college a subject whose intelligence is less than* 120, and *do not advise a subject whose intelligence is less than* 70 *to take mathematics and Latin.* Norms, laws, and administrative policies are inseparably connected in scientific societies.

Norms from practice. The method of obtaining norms from practice may be described generally. The first step is to understand the nature of the sources of data. Are they selective, or are they representative? If they are selective, the norm has no known significance beyond the data it summarizes. One might find out how public expenditures are distributed in cities of 2500 to 10,000 population, but he could not maintain that the resulting norms would apply to larger cities. To be representative, data must include all the facts, or an adequate sampling of all. If large numbers of cases are involved, sampling is usually resorted to.

The principles of sampling can best be obtained from texts in statistics. The process can be illustrated, as follows. An investigator has on record-cards the intelligence-test scores and arithmetic-test scores of 50,000 children, the cards arranged in order from the youngest to the oldest. He assumes that one out of four will give an adequate sampling. If there are three thousand eight-year-olds and six thousand ten-year-olds, the sampling would include 750 eight-year-olds and 1500 ten-year-olds. Each age-group would be represented in proper proportion. The probabilities are that the norms he would thus obtain would not differ materially from the norms he would have obtained had he used the records of the 50,000 subjects.

Using expert judgment. Expert judgment is sometimes used to tell which end of a distribution of practice is the good one. A study of the form of university control might reveal that the single board of lay trustees predominates, but it would not tell whether lay control is better than faculty

control. Mere existence is not a sufficient criterion of value.

Usually seven to nine judges are used in establishing norms. Judgment is expressed by *rating* and by *comparing*. To illustrate rating, assume that there are seven situations, or categories. The instructions to the judges are, "Put a 1 before the best, a 2 before the next best, a 3 before the next best, and so on down to the poorest, which should be ranked 7. If any are of equal value, give them the same rank." If the problem is to judge seven men in leadership ability, the instructions are to rank the best number 1, the next number 2, and so on. Then the average rankings for each person are computed and the final ranking found. If individual *A* was ranked 1, 3, 1, 2, 2, 1, 3, respectively, by seven judges, his average rank is 1.86.

The comparison method does not differ materially from the ranking method. To illustrate it, assume that the problem is to estimate the ability of a given individual to teach, administer, and do research work. The judge would first estimate the subject's ability to teach in comparison with his ability to administer, second his ability to do research compared with his ability to administer, and third his ability to teach compared with his ability to do research. These estimates might be expressed simply by using the words "poorer," "better," or by using five to seven qualitative terms, such as "much poorer," "slightly poorer," "slightly better," "much better." To calculate the reliability of the estimates they must be expressed quantitatively. This may be done in one of several ways:

1. Set an arbitrary value for the characteristic being used as the

standard (for example, ability to teach), and evaluate the other characteristics in respect to it. By assigning a value of 10 to the characteristic, one could run down the scale to 0 and up to 20. This would give a 20-point scale, but it can be made longer or shorter as desired. For simple estimates, this plan works satisfactorily.

2. Measure one characteristic against another in terms of standard deviations, expressed as plus for above, and minus for below, the limits being four or five. This is a generally satisfactory method.

3. Indicate a convenient number of points for the total, and distribute the values so that the sum of all the estimates of a judge equals the total number of points assigned. The number of points to be distributed among ability to teach, to administer, and to do research might be 100. With 30 for the first, 50 for the second, and 20 for the third, the total will give the original number, 100. Any individual being judged would be rated against each of these allowances: not more than 30 for ability to teach, not more than 50 for ability to administer, not more than 20 for ability to do research.

Quantitative derivation of norms. Enough has been said to show that norms are usually derived by calculation and measurement, just as laws are derived. The first step is to obtain suitable measuring instruments. If they have not already been prepared, the task must be performed before the investigation can proceed. The preparation of devices by means of which norms can be derived is one of the big undertakings before those engaged in research in normative sciences. Progress is being made, however. In education, nearly 600 devices for measuring intelligence, achievement, aptitude, and non-intellectual traits have been devised in the short period of twenty years. Many represent pioneer efforts, and are naturally quite crude; but rapid progress is being made in perfecting and refining the measur-

ing instruments. The normative sciences also use the standard measures of length, weight, volume, and force, wherever they will apply.

Because precise instruments of measurement have long been available in physics and chemistry, they are often called the exact sciences. Likewise, all other fields are known as the inexact sciences. These terms, exact and inexact, it should be remembered, are not absolute expressions, but represent all degrees of accuracy from the nearly zero to the not quite perfect. A better definition of *exact* than perfectly accurate is *accurate within known limits*, for this indicates that an allowance has been made for the ever-present error in measurement. Knowing what correction to make for the inaccuracy of a measuring instrument, it may be used precisely, notwithstanding the device is not absolutely perfect.

Devices used in deriving norms. The measuring devices used in deriving norms are various in number and kind. One of the simplest is *the score card.* This has been used extensively in agriculture, architecture, sociology, and education. The first step in making a score card is to list all the characteristics to be evaluated. The next step is to fix standard values for each item in the list. The main divisions are further divided and assigned lesser values. In making a score card with which to evaluate a public building, the investigator might first list as many as 100 separate items, grouped under four main headings: site, building, equipment, and details. With 1000 points for the total, experts would be called upon to allot the 1000 points to the four major headings and the many subheadings.

In using the score card, the thing being judged is compared with the standard, and evaluated accordingly. Three to five judges are commonly employed in making the comparison, and the median value given is accepted as final. The device has its uses, chiefly as a means of analysis and description from which more accurate measurements may be developed. It is probably not very reliable, and, on account of statistical limitations, the actual reliability is seldom known. This prevents it from being used in really scientific work.

Scales and tests. *The scale* is made of specimens of the thing being measured. They are arranged in a series, from the lowest to the highest. The order is often determined by competent judges. The thing being judged is compared with the samples on the scale. When the point is reached at which the specimen and the standard agree, the specimen is given the value formerly allotted to the standard. Scales are used in measuring color, handwriting, composition, light, and form (in art). Cloth specimens can be arranged in scales according to quality, color, and composition. Grain, cotton, flour, paper, arithmetical ability, and intelligence are a few of the many things that are or have been evaluated by the use of scales.

A third type of measuring device is *the test.* This differs from the scale, in that quantity rather than quality determines the score obtained. The test is used in measuring ability in such subjects as science, mathematics, Latin, history, economics, law, engineering, and other subjects Instead of measuring how much of equal tasks can be done in a specified time, tests may be devised to measure how

great difficulty can be achieved, either with or without a time limit. On the ordinary test, some items should be easy enough so that all who take it may make some score, and some difficult enough to test the very best; otherwise the ability of the very poor and the very good would not be measured. If all the items are of equal difficulty, the time allowance should be sufficient to permit all to make a score, and yet not so great as to allow the best to finish.

Norms may be obtained also from the ordinary data of record. From the books of county officials, one may obtain statistics as to the cost of government in cities, school districts, and townships. From such arrays of data, the central tendencies may be computed. Similar norms may be developed for states and for cities of the same rank in different states. Data on the volume of business of firms, of bank clearings, of exports, of stock sales, and any and every other transaction expressed in objective terms may serve as the basis for the central tendencies known as norms.

2. *Validity in normative science*

The meaning of validity. Validity is naturally a matter of vital concern in the normative sciences. After first determining that the sources of the proposed data are what they purport to be, the next step is to prove that the measuring device measures what it purports to measure. If no measuring device intervenes between the observations and the source or thing observed, as when one observes events directly, then the question of validity is merely one of determining whether the observations are what they purport to be, that is, phenomena of the thing observed. Given

tables and arrays of financial statistics; are they city expenditures as they purport to be? Are these estimates of the actual handwriting of school children? Are these estimates of the quality of cotton fiber? Such questions illustrate the meaning of validity.

To illustrate validity further, consider the case of the student who investigated college entrance requirements. For sources, he used college catalogues and reports obtained directly from the institutions in question. The authenticity of the catalogues might have been established: (1) by the seal, (2) the title page, (3) the letter of transmittal, and to some degree by the contents. The authenticity of the reports might have been established by: (1) signature of the registrar, (2) the seal, (3) corroborating letters, and (4) to some degree by the contents. One source may also be used to validate another, agreement then being the main test.

Validity of a measuring device. If a device measures a thing whose validity is assured, the validity of the device is established. *Use* is a test of validity. If a device works, it is valid. A test may be more valid than its criterion; it may measure a thing more accurately than competent judges can estimate the same thing; but in standardizing a measuring device, competent judgment is usually the best and simplest criterion to apply. As has been noted, Professor Terman, in standardizing his intelligence test, relied upon a criterion. The validity of the test was expressed by the correlation coefficient between the actual test results and the estimates of the judges.

In calculating validity, the Pearson product-moment formula for correlation is used. It is as follows:

$$r = \frac{\Sigma xy}{n\sigma x\sigma y}$$

in which r is the coefficient of validity, xy the product of the xy variables, and σx and σy the standard deviation of the x and y variables.

If a number of criteria are used, they may be pooled, and a single validity coefficient derived by applying a formula devised by Professor Spearman. With n criteria, the first term in the formula becomes $r_c\ (z_1 + z_2 + z_3 \ldots\ldots + z_n)$, in which r_c is the correlation between the test and its criterion; z_1, z_2, and z_3 the product obtained by dividing the deviations from the mean by the standard deviation, z being called a standard score. With two criteria, the formula becomes:

$$r_c\ (z_1 + z_2) = \frac{2\, r_{cz}}{\sqrt{2 + 2\, r_{zz}}},$$

while the general formula is:

$$r_{cn} = \frac{nr_{cz}}{\sqrt{n + n\ (n - 1)\ r_{zz}}}.$$

Validity is dependent upon the degree to which the coefficient approaches 1.00 as a limit. Thus of two validity coefficients covering the same range of talent, the one having a validity coefficient of .935 is more valid than one having a coefficient of .786.

Reliability in normative science. Reliability expresses the accuracy of the observations. Observations are accurate to the degree to which repeated measurements obtain the same results. An instrument which changes as a balance whose spring becomes weak, or a metal tape which

expands with heat, loses reliability. When observations are made directly without the intervention of a measuring instrument, reliability is tested by calculating the extent of agreement obtained from successive observations by the same observer, and by different observers. If one observer, studying the newspapers of California to find the attitude towards Orientals, obtains p results, later observations of the same materials must also obtain p results if they are to be counted reliable.

When a measuring device is applied, or when results are expressed quantitatively, reliability is calculated by correlating results obtained on chance halves of the device, or by correlating successive measurements. The higher the positive correlation, other factors being equal, the greater the reliability. Devices having a reliability of .80 (with low probable error) give norms that represent groups accurately enough, but for purposes of individual diagnosis are too low. For individual diagnosis the reliability should be above .90.

Reliability of observations may be increased by: (1) making more observations, and (2) by lengthening the test. In the event that it is not practicable or possible to make more observations, or if the range of sampling is narrow (six-year-old children, individuals of superior intelligence, small cities, etc.), a correction formula may be applied which will give the results normally to be expected when observations are adequate and fairly distributed. The correction for attenuation is made by the formula:

$$r_{st} = \frac{r_{12}}{\sqrt{r_{1I}\,r_{1I}}},$$

while the formula for predicting the reliability of a lengthened test is:

$$r_{nn} = \frac{nr_{1I}}{1 + (n-1)\,r_{1I}}$$

The criterion in normative science. An essential principle of normative science may be expressed by explaining the use of the criterion. A norm is always an expression of value in comparative, not absolute, form. One cannot arrive at teaching ability in an individual except as that ability compares with the ability of others in teaching, and with his own ability in accounting, research, stenography, or other measurable characteristic.

The value of a measuring device can be assumed if it distinguishes between those who have the characteristic under consideration and those who do not have it. A test which gives high scores to farmers and low scores to artists is not a test of artistic ability. The beginning point of social measurement may therefore be conceived of as separating those who have a quality in high degree from those who do not have it, or who have it in slight degree: that is, in observations of leaders and non-leaders, actors and non-actors, teachers and non-teachers, etc.

By such means, a criterion may be established as truly as by the use of competent judges. Zyve's study of scientific aptitude is a good illustration.[3] He gave *Form A* of his test to 79 freshmen who were planning to follow some branch of science; to a group that *presumably* had scientific ability. He gave equivalent *Form B* to 246 freshmen representing all

[3] D. L. Zyve. *An Experimental Study of Scientific Aptitude*, pp. 153–55.

the departments of the university; to a group that presumably did not have scientific ability. The scores on *Form A* made by the science group gave a higher norm than the scores on *Form B* by the non-science group. The correlation between the two forms was .90 ± .019; which, when corrected for attenuation, gave a reliability coefficient of .93 ± .014. This test distinguished between students not believed to have scientific ability and students believed to have scientific ability, and did it with a high degree of accuracy.

If the criterion is established by competent judges, the reliability of their estimates must also be calculated. Those estimates which approach most closely to the pooled estimates are accepted as the most reliable. A formula for computing the reliability of the estimates of judges has been devised.[4] It is stated as follows:

$$r_{1I} = \frac{(a-2)\ \bar{r}^2_{1p}}{ar_{pq} - 2r_{1p}}$$

in which a equals the number of judges, $\bar{r}_{pq}$ the average intercorrelations weighted according to population, and $\bar{r}_{1p}$ the average correlations of one judge with another, weighted according to populations.

Verification of norms. Once norms have been established they may be verified in the same way that any other principle may be verified — by submitting them to the test of trial or experience. If they work, they may be correctly held to be true. An investigator finds that the median

[4] Eugene Shen. "The Reliability Coefficient of Personal Ratings," pp. 232–236.

class in city schools contains thirty-eight pupils. This is the norm of practice. Is it the best standard? This question can be answered by actual trial and experiment. Suppose he submits the question to the judgment of competent judges, who fix the standard at thirty. There remains, in either case, the necessity for trying it out.

A norm is true when it can be brought under an already established general principle or theory. A method of doing this is to find the mathematical curve which fits the data. By this means, the law to which the observations conform is revealed, and a basis for prediction is laid. All data, when sufficiently extensive, usually tend to take on some regular form which can be described mathematically; much data take well-recognized forms which fit other kinds of facts. If the data do take well-known forms, the problem is to select the curve which best describes the given facts, and to make calculations showing how well the curve fits the facts.

The normal probability curve is a good example of a distribution commonly taken by the facts of physical characteristics. This is a bell-shaped curve, symmetrical about the mode; the mode, median, and mean coinciding. It falls off at the base at the distance of about five standard deviations from the mean. The test of normality consists in superposing the normal curve upon the observed data, with a mathematical comparison of the normal and the obtained frequencies. The formula for the normal curve is:

$$y = \frac{n}{\sigma\sqrt{2\pi}} \cdot \frac{1}{e^{x^2/2\sigma^2}}.$$

This formula gives the value of any ordinate, y, at any

distance x (measured along the base from the mean). e is a constant, 2.71828, the base of the Naperian system of logarithms. n is the total area of the curve or the number of observations, and σ is the standard deviation. Tables are used when comparing any derived curve with the normal curve. To find the closeness of fit, the difference between the actual frequency of each class and the theoretical frequency is found, and the square of this difference is divided by y. The square root of the sum of the quotients thus obtained is the index of closeness of fit. The probability that the data are truly represented by the normal curve may then be calculated by a method devised by Pearson.[5]

Not all physical characteristics are normally distributed. As examples of those which are probably normally distributed there may be cited height, intelligence, brain weight, length of bones, pigmentation, and cephalic index. Scores of normally distributed characteristics may be found among lower animals and plants. Among non-uniform distributions, Davenport cites certain flower petals, wings of insects, and rays of shell-fish. The significant point to this discussion is: *normality can never be assumed; it should always be tested.*

Expressing values. A norm has been defined as a central tendency in a distribution of data. It signifies that the observations themselves are distributed over a range from high to low, superior to inferior, etc. The significance of the central tendency as a description of the whole distribution grows out of the fact that, in large arrays of data, most of

[5] See C. B. Davenport. *Statistical Methods*, pp. 22–41, or other texts in statistics.

the cases tend to pile up about the mean, which therefore describes more facts than any other value.

Since values along a range may be used to express standards, it is useful to know what percentage of the observations are to be found between any two intervals, or above or below any interval. For example, we ask what percentage of the population is over sixty years old, what proportion of all males are over six feet high, what proportion of school children made scores above 100 on an intelligence test? The value of a characteristic above or below which a given percentage of the observations lie is called a percentile, usually denoted by the symbol P. The value of a percentile is given by its subscript. P_{25}, P_{50}, P_{75} mean that 25 per cent, 50 per cent, and 75 per cent of the observations, respectively, lie below the given points on the distribution. Likewise, a percentile of 25 means that 75 per cent of the cases lie above it. The formula for calculating the percentiles is exactly the same as the formula for calculating the median, P_{50}.

The frequency method of calculating percentiles, devised by Francis Galton, furnishes an easier approach to an understanding of their meaning. The observations are first arranged in a table, in descending order. Opposite the lowest value is placed the frequency of its occurrence. Opposite the next lowest value is placed the frequency of its occurrence, *plus* the frequency of the first or lowest value. In this way, the table is built up, adding the new frequencies to the old total until the highest value is reached. Opposite to this highest value is placed the total number of frequencies. Each cumulative frequency is next divided by the total

frequency to obtain the percentiles. The table below furnishes an illustration of a percentile table, the values being scores made on an achievement test, the number of cases 200, and the range of scores from 36 to 71.

TABLE I.

AN ILLUSTRATION OF GALTON'S METHOD OF CALCULATING PERCENTILES *

Scores on Test	Frequency of Scores	Cumulative Frequency	Percentile Distribution
71	2	200	100.0
70	1	198	99.0
68	1	197	98.5
65	3	196	98.0
64	4	193	96 5
63	7	189	94.5
60	8	182	91.0
58	11	174	87.0
57	15	163	81.5
55	17	148	74.0
54	20	131	65.5
53	24	111	55.5
52	21	87	43.5
51	18	66	33.0
50	15	58	29.0
49	10	43	21.5
48	7	33	16.5
47	8	26	13.0
45	3	18	9.0
44	7	15	7.5
42	5	8	4.0
40	2	3	1.5
36	1	1	0.5

* Read the last column as *percentage making the given score or less.* For example, 74 per cent made the score of 55 or less.

With a scale of this kind, any observation can be located with respect to all others. For example, take an individual who made a score of 55 on the test. Reading from the table, one finds that 74 per cent made the same grade or less; or, to

put it in another way, only 26 per cent made higher scores. The subject ranks with the best 27 per cent — approximately with the best one fourth of the group. The curve of this distribution may easily be plotted, using percentiles for the base, and scores for the ordinates. The result is the peculiar type of curve called the ogive. Such a curve is a useful measuring instrument.

The nomograph. The nomograph is another convenient method of expressing values in normative science. The word is derived from the Greek, *nomos*, a law, and *graphos*, a writing or representation. A nomograph is literally a way of describing a law. According to Marshall,[6] it is "A graph composed of lines scaled relatively, and placed in such relative positions that the values of the variables are found on a line crossing the scales."

The literature of the nomograph is to be found mainly in French and German. The device has been used most extensively in engineering in facilitating calculations in engine design, in hydraulics, pneumatics, specific heat and specific volumes of steam, induction motors, illumination, navigation, marine engineering, strength of materials, stresses and strains, and in the determination of areas and volumes. Applications have also been made to medicine; a smaller number to education; practically none to other social sciences.

The nomograph satisfies the demand for a device by which an equation of the type:

$$x + y + z = 0$$

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[6] W. C. Marshall. *Graphical Methods*, p. 169.

may be represented without recourse to a system of axes with a common origin. Ten main forms of the equation have been derived, each of which can be modified in a number of ways, thus increasing the number of applications. Examples of simple equations which can be expressed in nomograph form are given as follows:[7]

$$A + B = X \quad \ldots \quad (1)$$
$$AB = X \quad \ldots \quad (2)$$
$$A:B::C:X \quad \ldots \quad (3)$$
$$(A + B)C = X \quad \ldots \quad (4)$$

As an example of nomograph construction, a problem has been selected that often occurs in school surveys; namely to estimate the needs, ability, and performance of a district. The first step is to derive the equation. This was found to be as follows: $P^2 = .815NA$, which means that, on the average, the cities of the United States spend such an amount on education that the square of their performance equals .815 times their ability multiplied by their needs.

With the factors decided upon, the required data were collected and assembled in tables. The next step was to derive the equation connecting the variables A, N, and P. As a result, the average ratio between A and P was found to be 82.6.

This may be written

$$A = 82.6\ P \text{ or } P = \frac{A}{82.6}.$$

The average ratio between P and N is 67.2, or $P = 67.2\,N$. Multiplying both sides of the last equation by P we have:

[7] See J. C. Almack and W. G. Carr. "The Principle of the Nomograph," pp. 344–45.

$$P^2 = 67.2\ NP.$$

Substituting, in the right member, the value of P in terms of A from above, we have:

$$P^2 = \frac{67.2}{82.6} NA \text{ or } P^2 = .815NA.$$

To solve this equation, the sample nomograph has been given. (See Figure 1).

Summary. A norm is a standard of value representing a central tendency. With all the disadvantages of norms and standards, they offer the most satisfactory means of deriving and expressing the data of social sciences. Although many measuring instruments have been prepared, there is still a great need for valid and reliable devices. Progress is being made. The necessary statistical technique is being acquired, calculating machines are being improved, and new techniques are gradually being evolved. In every field a beginning has to be made, and no one need apologize, in the infancy of a science, for using crude instruments of measurement. In the end, the results of normative methods are subjected to just as severe tests as the laws derived from experiment.

EXERCISES AND PROBLEMS

1. Examine ten theses designated by the instructor, and report: (*a*) nature of the measuring devices used, (*b*) nature of the measuring instruments derived.
2. What is the difference between a scientific norm and a statute law? Between a norm and a moral law?
3. Explain why more progress has not been made in the establishment of norms.

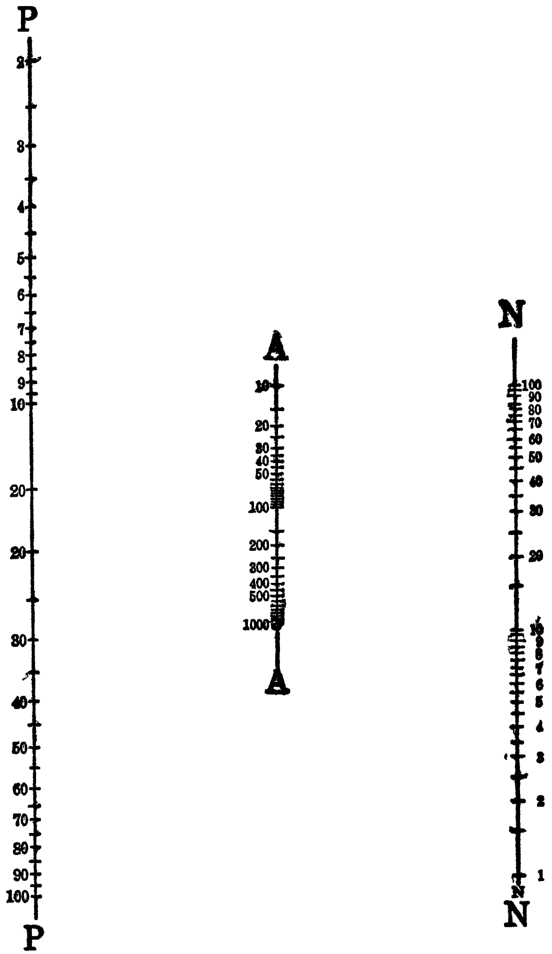

FIGURE 1. NOMOGRAPH TO SOLVE THE EQUATION CONNECTING EDUCATIONAL NEED, ABILITY, AND PERFORMANCE

$P^2 = .81\ N.A.$

4. Point out as many conditions as you can where the use of scientific norms would be helpful to individuals and to society.
5. Find an illustration of research resulting in a norm. How was the reliability of the norm established?
6. Show how norms result in laws and how laws may determine administrative policies.
7. Find examples of measuring scales. Of tests. Of other devices used to establish norms.
8. Explain why reliability is increased by lengthening a test.
9. Show what is meant statistically by reliability of the estimates of judges.
10. Show the practical value of knowing how to fit curves to data.
11. Point out as many human characteristics as you can that are assumed to be normally distributed. How can such an assumption be tested?
12. Examine a thesis in which: (*a*) normal distribution was assumed, or (*b*) the nature of the distribution was tested, and discuss the relative scientific worth of the results.
13. What is meant by a criterion group? Find a piece of research in which a criterion group has been used.
14. How can norms be verified? Is there any difference in the process of verifying norms and the process of verifying natural laws? Discuss.
15. Discuss the merits of the percentile distribution as a means of expressing the results of social measurements.

PROBLEM 9

Establishing Normative Relations

Situation 9: A candidate for the M.A. degree advanced the hypothesis that persons of intelligence tend to have a keener sense of humor than those of low intelligence. He wishes to test out his hypothesis for a thesis.

On investigation, he found a number of intelligence tests of sufficient reliability to meet his need. He was not successful, however, in finding a sense-of-humor test. He decided, therefore,

to prepare such an instrument. Although he has had courses in statistics, he is almost wholly unacquainted with the process of standardizing a measuring instrument. He wishes simple but adequate directions, and in the briefest possible compass.

Problem 9–A: What directions for standardizing a test should be given him?

Problem 9–B: How can he find out whether intelligence and sense of humor are associated, after his test is completed?

Special questions:

1. Suppose he discovers that there is no significant correlation between intelligence and sense of humor? Will he have a thesis?
2. Is a thesis of this kind likely to be of any practical value?
3. Would it be advisable to judge sense of humor as ability to write humor, estimating the value of each item produced by matching it against a scale?
4. Is it wise to learn a technique or process by actually engaging in it, or would it be better to take a general course in test-making first?

Bibliographical note: The best thing to do is to read reports on how tests have been standardized. See also, L. M. Terman, *The Measurement of Intelligence,* and Selected References, Brown, William, and Thompson, G. H.; Garrett, Henry E.; Holzinger, Karl J.; and Kelley, T. L., *Statistical Methods.* Books on objective tests and educational measurements in general offer another source of information.

PROBLEM 10

Is the Norm Truth?

Situation 10: Mr. Elwell is a graduate student in the department of political science. He has chosen for the subject of his master's thesis a study of the distribution of expenditures in cities listed in *Statistics of Cities.* He has found complete data on 220 cities, out of a total of 230.

He proposes to find how expenditures are distributed: what percentage goes for parks, what for police protection, what for fire protection, etc.; to find the norm (median) of the distribution of expenditures for each purpose; and to prepare percentile charts of each budget item.

In discussing his proposals, before the research seminar, he met with serious criticism. It was decided that his important results would be the norms for each item. The question then arose, "Are these norms truth?" Several of his fellow students took the negative of the proposition. "Suppose," they said, "the normal expenditure for item *X* equals 7½ per cent of the total budget this year. Is there any assurance it will equal that next year, the year following, and every year on to the end of time? On the contrary, it is probable the norm never will equal 7½ per cent again. Since the results are not fixed and certain, how can any one claim he has discovered the truth?"

Furthermore, it was pointed out that what is characteristic of the norm just described is characteristic of all norms. They are relative; they change. "It is like trying to fix a spot in the swift current of a flooded stream," some one remarked.

Mr. Elwell feels that he must answer the fundamental question involved before he proceeds with his work.

Problem 10: Weigh this question and reach a decision, either for or against the norm as a proper result for a thesis.

Special questions:

1. Would the value of his results be enhanced if he extended his study over a longer period?
2. Does the norm vary, or do individual cities vary without having any effect upon the norm?
3. If the norm does vary, cannot the limits within which it varies be calculated? If the probable error is known, are not the results then exact?

Bibliographical note: Refer to some good book on statistics, and read what is said about measures of central tendency and their error. Perhaps it would be well to frame an acceptable definition of truth, and to keep in mind what was said in another chapter about the tentative nature of science.

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CHAPTER VI

THE EXPERIMENTAL METHOD

1. *The problem basis*

Beginnings of experimentation. The sixteenth century is known as the age of discovery. In this period the world was made known to man. Columbus ventured into the unknown western seas and discovered the new continent of America. Vasco da Gama rounded the Cape of Good Hope and discovered the long hoped for sea route to India. These pioneer voyages were followed by exploration on every hand, while the voyages became more detailed and the explorations more complete and accurate, until all but the cold continents around the poles had been trodden by man. Magellan circumnavigated the globe in 1519–22; Drake sixty years later. By 1600, the maps of the world were accurately drawn, and only a few areas were undiscovered.

It was an age of scientific exploration. In 1543, Nicolaus Copernicus published his *De Revolutionibus Orbium Celestium,* in which he declared that the earth is spherical, and that the motions of the heavenly bodies are uniform circular motions. He was followed by a careful observer, Tycho Brahe, who supplied adequate data to support the Copernican theories. Brahe's pupil, Kepler, just at the close of the century, formulated the famous three laws of planetary motion. Like the great voyages of Columbus and da Gama, these discoveries were but the beginning of a period of pains-

taking and directed investigation known as experimental science.

For Copernicus, Brahe, and Kepler were observers, not experimentalists. Experimental science commenced with William Gilbert, born in 1544. He was a successful physician. He insisted upon the necessity of having an experimental basis for all science. His tendency was to put every argument and statement to the test of experiment. When an Italian philosopher taught that iron is magnetized by being rubbed with diamonds, Gilbert made the experiment "with seventy-five diamonds in the presence of many witnesses," varying conditions many times to take account of possible interfering factors, but, he says, "Never was it granted me to see the effect mentioned by Porta."

Galileo Galilei and Gilbert were of the same age. Appointed professor of mathematics at the University of Pisa, Galileo soon found himself unable to sanction the doctrines of Aristotle. One of the views of this philosopher was that the rate of falling bodies is proportional to their weight: that is to say, a body weighing ten pounds would fall from a given height in one tenth the time of a body weighing one pound. No one would lay much claim to originality nowadays in trying out such an hypothesis, but the actual experiment by Galileo was an epoch-making event. From the leaning tower of Pisa he dropped balls of different sizes and weights, finding that all reached the earth at nearly the same time. Reasoning from his results, he decided that, except for the resistance of the air, all bodies would fall at the same rate, independent of their weight. After confirming his first findings with further tests, he formulated the law of falling bodies: *the*

distance of descent is proportional to the square of the time. This law is expressed as $S = \frac{1}{2} gt^2$.

Experiment and law. From the time of Gilbert and Galileo there have been an increasing number of persons who refuse to accept authority, and insist on "trying it out." The result of experiment is a law, "a statement of the uniform behavior of natural phenomena," or, as is often said, "laws are conditioned statements of what happens." The conditional character of laws explains why science is positive and sure of its ground. Its laws are always stated or can be stated so as to begin with a conditional clause: an *if* or *when* clause. "*If* the pressure of a gas increases, and if its temperature remains the same, its volume decreases"; "*When* hydrogen and oxygen are brought together under proper conditions, water is produced."

Natural law is not to be confused with statute law and moral law. Statute law is a law of *must.* If it is disobeyed, certain penalties are attached; perhaps fine or imprisonment, or both. Moral law is a law of *ought.* As long as one keeps within the letter of the statute law he can escape legal punishment; the violation of moral law usually carries with it a loss of respect and confidence, and may lead to social ostracism. No penalties are attached to natural laws because they are never broken; they are enforced by the facts upon which they are based.

A new law is discovered by a process called *induction.* By this process, the experimenter passes gradually from particular instances and facts to a generalization which comprises them. In the early days of science, nearly all of these particular instances came from observation of the world round about, but generally, since the time of Gilbert

and Galileo, the particular instances are obtained under controlled or experimental conditions. When an observer uses a microscope to view a small object, he is not experimenting because he is not modifying or changing the thing being observed. If he heats the object or treats it with a chemical, he is beginning to experiment. Experiment is observation under artificial conditions; that is, conditions produced or arranged by the observer.

In actual fact, it is hard to mark off a sharp line between "natural observation" and controlled experiment. The selective type of observation midway between no control and complete control is sometimes called "natural experiment." Jevons says:[1]

> When the earliest astronomers simply noticed the ordinary motions of the sun, moon, and planets, they were pure observers. But astronomers now select precise times and places for important observations. They make the earth's orbit the basis of a well-arranged *natural experiment,* and take well considered advantage of motions which they cannot control. Meteorology might seem to be a science of pure observation, because we cannot possibly govern the changes of weather which we record. Nevertheless, we may ascend mountains, or rise in balloons and aeroplanes, and may thus so vary the points of observation as to render our procedure experimental.

This quotation is sufficient to make clear certain salient facts concerning controlled experiment. The thing observed must be modified. Experiment cannot be conducted simply by using instruments of precision. They add to the accuracy of observation, but do not affect the thing being observed. The use of a microscope permits observation of

[1] W. S. Jevons. *Elementary Lessons in Logic,* pp. 400–01. Reprinted by permission of The Macmillan Company.

smaller objects and in greater detail; the use of a telescope permits observation at greater distance; the use of a chronometer enables one to measure time more accurately; but the use of none of these changes in any way the phenomena under observation.

The fields of experimental science. Certain subjects are regarded as the experimental sciences, *par excellence*. Oldest of these are physics and chemistry; of growing interest are biology and its derivatives, botany and zoölogy. Psychology, when it treats the behavior of man under conditions that can be repeated, is experimental, but under such conditions is rightly to be looked upon as a derivative of biology. While medicine is not properly experimental, it can have no other satisfactory basis. Engineering has marked experimental aspects; in fact, without experiment engineering would be so costly and so dangerous as seriously to limit its usefulness. Nearly all the processes of education and business are subject to controlled experiment.

Sociology is almost purely normative and historical; only within a limited range is social experiment possible, for social events cannot be controlled nor exactly repeated. History, of course, lays no claim to being an experimental science. Within a sense, its events may be duplicated; they can never be controlled or repeated. Astronomy and geology approach closely to the experimental sciences; enough indirect control is possible to warrant the use of the term *natural experiment*. The best practice is to limit the application of experimental science to phenomena which can be controlled, and whose data can be verified by exact repetition.

Experiment and induction. The nature of the inductive process, the process by which natural laws are drawn from data, can best be learned through an illustration. Torricelli was a disciple of Galileo. He was familiar with the fact that water could be raised in a pipe by a suction pump to a height of 32 feet. He reasoned that when the air was exhausted from the pipe by suction, the weight of the air on the water of the well tended to force water into the vacuum and up the pipe to a point where the column of water exactly balanced the weight of the column of atmosphere. The problem was to test this hypothesis.

Since a column of water 32 feet high is unwieldy to handle, Torricelli substituted mercury. The specific gravity of mercury is 13.6, which means it is 13.6 times as heavy as water. He then selected a glass tube four feet long, and closed one end of it. He filled this tube with mercury, and inverted the tube, with the unsealed end in a vessel of mercury. The mercury at once fell away from the top of the tube until it stood at thirty inches high. The weight of thirty inches of mercury is exactly the same as the weight of 32 feet of water (32 feet divided by 13.6 equals 30 inches, or $2\frac{1}{2}$ feet). In this experiment, Torricelli proved that the height to which a liquid rises in a vacuum tube is proportional to the weight of the atmosphere; or, more specifically, that the weight of the atmosphere is sufficient to sustain a column of water 32 feet high.

The later experiment of Pascal gave further support to the law. He carried the mercury column (the barometer) up the side of a mountain to the height of three fifths of a mile, where he found "the mercury column was about three inches

shorter," which meant that the weight of the air had diminished. To-day, all the essentials of the experiments of Torricelli and Pascal may be performed in a laboratory with the aid of an air pump, a bell jar, and a barometer. From the laboratory tests, the experimenter can go directly to the general principle of atmospheric pressure. This process of going from particular observations to the general principle is called *induction*: literally, *the act of leading in.*

The famous kite experiment of Franklin also can be used to illustrate the relation between experiment and induction. This was described, as follows:

> To the top of the upright stick of the kite is to be fixed a very sharp pointed wire, rising a foot or two above the wood. To the end of the twine, next the hand, is to be tied a silk ribbon, and where the silk and twine join, a key may be fastened. This kite is to be raised when a thunder-gust appears to be coming on, and the person who holds the string must stand within a door or window, or under some cover, so that the silk ribbon may not get wet; and care must be taken that the twine does not touch the frame of the door or window.
>
> As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine, will be electrified, and the loose filaments of the twine will stand out every way and be attracted by an approaching finger. And when the rain has wet the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key, the phial may be charged; and from electric fire thus obtained, spirits may be kindled, and all other electric experiments be performed, which are usually done by the help of a rubbed glass globe or tube, and thereby *the sameness of the electric matter with that of lightning completely demonstrated.*

So far as the writer is able to see, there is no gap between the facts and the generalization. The law grows as naturally

out of the facts as a tree from the soil. Strands of the truth are woven as the data appear; they merge at last into a single embracing whole. What has been called the "inductive leap" probably signifies insufficient or obscure data. Facts are the material out of which generalizations are made: how can there be a break between them?

The experimental process. Like all other forms of research, the experimental process begins with a problem. The brilliant work of Spallanzani was done to discover whether microbes have parents, or are spontaneously generated. Metchnikoff conducted his experiments to find out whether the white blood cells destroyed harmful bacteria. Pasteur answered the question: "Do bacteria cause disease?" Nature, like the Sphinx, will not speak until she has been asked a direct question.

After the problem is formulated, the next step is to set up an hypothesis. If the experimenter has no hypothesis, he cannot proceed to do research; he can only grope about by the trial and error method; he can only feel about blindly for a clue. Often this blind groping is necessary.

Claude Bernard, the experimental physiologist, gives an illustration that is applicable. He wished to discover the effect of carbon monoxide, but knew so little about it that he could frame no hypothesis. He therefore administered the gas to an experimental animal, dissected it, and observed what effects he could. Most pronounced was the observation that the venous blood was bright red, as if the blood cells were filled with oxygen. He then formulated the hypothesis that death resulted because diffusion of oxygen from the blood and carbon dioxide from the tissues was

someway rendered impossible by the monoxide. The next step was to put his hypothesis to the test.

As soon as the hypothesis has been framed, the experiment may be begun. Observations are made and recorded, and a tentative generalization made. To establish reliability, the experiment is repeated. As soon as the cause or basic principle has been discovered, it is applied under life conditions, or under conditions as near to the natural as possible. If the effects predicted are obtained, the law is considered valid.

A further example of the process may be seen by describing an experiment performed by Spallanzani. An Englishman named Ellis published a paper denying the truth of the hypothesis that microbes multipled by cell division. He declared that what had been described as cell division was simply one of those small animals coming into contact with another and breaking it in two. Spallanzani determined to find the truth of the matter. "All that I have to do," he reasoned, "is to isolate one microbe, watch it under the microscope, and see if it divides."

Ingeniously he managed the isolation of the microbe. As he watched it under the glass, the little rod-shaped body commenced to get thinner and thinner in the middle. Finally the two parts were held together by a thread of infinitesimal thickness. Soon this thread separated. Swimming about in the drop of water were *two* tiny animalcules formed by cell division, and not by accidental collision with another. De Kruif says:[2] "He did this ingenious trick a dozen times and got the same results and saw the same thing."

[2] Paul de Kruif. *Microbe Hunters*, p. 54.

Analysis and experiment. In the experiment by Spallanzani, the bacterium being studied was first isolated. There was no possibility of its being separated into two parts by being struck by another microbe. Here is illustrated a basic rule in experimentation: *permit only one factor to be operative at a time.* Only in this way is the experimenter able to tell whether the factor produces an effect or not. If he considers factors *a*, *b*, and *c* at the same time, how is he to know whether the effect, *e*, is due to *a*, *b*, or *c*; to *ab*, *ac*, *bc*, or even to *ad*, *b*, etc.? He has not solved his problem until the connection of a single factor to the effect is known.

Analysis is the process by which is derived all the factors that might produce the given effect. To one of these factors, the term antecedent is applied; to the effect or to the event which follows, the name consequent is applied. Suppose the explanation of a principle, *p*, resides in one of ten factors, *a*, *b*, *c*, *d*, *e*, etc. A trial is made with factor *a* omitted. If *p* appears the conclusion is that *a* is *not* its cause. Repeating the trial with *b*, *c*, *d*, etc., omitted in order, the discovery is made that only when factor *g* is omitted does the phenomenon fail to appear. The conclusion then is that factor *g* is the antecedent of the consequent, *p*.

Each factor supplies the foundation of an hypothesis. Analysis having revealed that the explanation is to be found in either factor *a*, *b*, or *c*, the experimenter first assumes that factor *a* is the essential antecedent. He proceeds to try out *a*. If *a* does not prove to be the essential antecedent, he assumes that factor *b* is the essential factor. He tries out *b* next, and so on until the correct antecedent is found.

Among a number of hypotheses, one will have to the experimenter an appearance of greater probability than the others. This is the one he will test first. Any hypothesis that cannot stand the test, will, of course, be discarded, no matter how plausible it appeared nor how dear it is to the heart of the investigator. The hypothesis is for the experimenter, not for the layman, "yet, as a matter of fact, the wildest speculations are likely to be the ones that excite most popular attention and applause."[3]

The number of experiments necessary is determined by the number of factors. If there are eight factors, and one is excluded with each experiment, the total number of experiments to perform is $(8 - 1)$. If one factor is combined with every other factor, the number of experiments to perform is

$$\frac{n(n-1)}{2}.$$

2. *Canons of experimentation*

Mill's five canons. Mill gives five canons of experimentation. They are classified under five "methods," as follows: (1) the method of agreement, (2) the method of difference, (3) the joint method of agreement and difference, (4) the method of concomitant variation, and (5) the method of residues. For these methods, Mill acknowledges his debt to Francis Bacon and John Herschel. Bacon borrowed from Gilbert the principles of the famous tables of: (1) presences, (2) absences, and (3) degrees; the germs of Mill's methods of agreement, difference, and concomitant variation.

[3] T. H. Morgan. *Experimental Zoölogy*, p. 6.

The first two, agreement and difference, are oftenest mentioned. In discussing the method of agreement, Mill stated that the simplest and easiest ways of singling out, from the circumstances which precede or follow an event, those factors with which it is connected by an invariable law are two in number: (1) by comparing together different instances in which the event occurs, and (2) by comparing instances in which the event occurs with events in which it does not occur. The three other methods are regarded as dependent upon the first two. From the point of view of experimental science, only one, the method of difference, is of essential significance. Robinson calls Mill's method of difference the method of experiment *par excellence.*[4]

The method applied. Mill states the method of difference as follows:

> If an instance in which the phenomenon occurs, and an instance in which it does not occur, have every circumstance save one in common, that one occurring only in the former; the circumstance alone in which the two instances differ, is the effect or cause, or a necessary part of the cause, of the phenomenon.[5]

All factors except the one suspected of being essential, are kept constant, and the suspected factor is taken away. If the effect disappears along with the factor, then one knows that the factor is causally related to the phenomenon. Hence arises the rule, *only one factor can be varied at a time.*

The factor which produces the effect or which accompanies the effect is called the *essential factor,* for without its presence the consequent does not appear. If *R* (result) invariably

[4] D. S. Robinson. *The Principles of Reasoning,* p. 264.

[5] John Stuart Mill. *Logic,* book III, chap. IX.

follows a, but does not follow b, c, or d, then a is the essential factor. This process illustrates the method of agreement. If R follows a, b, c, d, but not b, d, c, then a is again the essential factor. This process illustrates the method of difference. If R varies with a, but not with b, d, and c, by the method of concomitant variation a is the essential factor. If R minus c equals a plus b, and b equals c, then, by the method residues, a equals R. If R follows a, b, c, d; a, m, n, d; a, r, s, d, both a and d are essential factors; but if b, c, d is followed by D (not $- R$), and d, e, f by D (not $- R$), then, by the joint method of agreement and difference, a is the essential factor.

Pasteur laid down the hypothesis that treating sheep and cattle with vaccine would prevent them from contracting anthrax in a severe form. He vaccinated 24 sheep and "several cattle." A few days later he injected anthrax germs into the 24 sheep and the "several cattle" previously vaccinated, and into 24 other sheep and "several cattle" not previously treated with the vaccine. None of the vaccinated animals died; none were, so far as could be discovered, affected by the anthrax vaccine. All of the animals not vaccinated died of anthrax. In this experiment:

V (the vaccine) is the essential factor (assumed).
It is tried out by the method of difference.
It proves to be the essential factor.
The law is formulated, "Vaccine will protect sheep and cattle from anthrax."

Joseph Goldberger laid down the hypothesis that pellagra is due to dietary deficiency. If this is true, he argued, pellagra can be induced by putting subjects on a diet restricted

mainly to carbohydrate cereal. His subjects were 11 male white convicts, the place the prison camp of the Mississippi State Penitentiary, near Jackson. The subjects were placed under observation from February 4 to April 19 to see if any had pellagra. None had the disease and, on April 19, the experiment commenced. From this date until October 31, the prisoners were fed a carbohydrate cereal diet. The other inmates of the camp were fed a well-balanced diet. Other conditions were identical for both groups; only the essential factor, diet, differed. The 11 convicts constituted the *experimental* group, the other convicts the *control* group. By the end of five months, six of the subjects had developed pellagra; none of the controls developed it. In this experiment

Carbohydrate cereal diet is assumed to be the cause of pellagra: that is, the essential factor.

It is tried out by the method of difference.

It proves to produce pellagra in six of the subjects.

The law is formulated, "A carbohydrate cereal diet will induce pellagra."

The problem confronting Theobald Smith was to discover the cause of Texas fever. His hypothesis was that the fever is carried from a sick animal to a well one by ticks. He found that northern cattle enclosed with southern cattle would take the fever if the ticks were not removed from the southern cattle; he found they would not take the fever if the ticks were removed, even if they were enclosed in the same pen with sick animals. He then induced Texas fever in northern cattle by putting ticks from southern cattle upon them, though the two herds were kept in separate

pastures. Finally, he induced the fever in northern cattle in winter time by putting artificially propagated infected ticks upon them.

Correlation *versus* experiment. To a limited extent, the influence of several factors may be estimated independent of experimentation. Assume that several causes combine to produce a given effect, the question is what weight should be attributed to the different factors. To illustrate, take a school situation in which there are the following data: (1) reading scores, (2) intelligence test scores, and (3) arithmetic scores. By the method of partial correlation, the influence of each factor is thrown out in turn until there is left the correlation between any two factors: i.e., reading ability and arithmetic ability, with the factor of intelligence thrown out.

The formula is as follows:

$$r_{12.3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{1 - r^2_{13}}\sqrt{1 - r^2_{23}}},$$

in which r_{12} is the correlation between factor 1 and 2, r_{13} the correlation between factor 1 and 3, and r_{23} the correlation between factor 2 and 3. This is the mathematical equivalent of experimentation by the method of difference. By the multiple correlation method, the weight which should be assigned to each factor in a complex of causes may be calculated. The method is not an adequate substitute for experimentation, and its conclusions should not be accepted as final.

Subjects in experiment. Whatever is experimented with is called the subject or subjects. Pasteur's subjects in the ex-

periment just described were sheep and cattle; Goldberger's subjects were convicts; Smith's subjects were cattle. A subject may be an iron bar, a Leyden jar, a beam of light, a magnet. The process of experimenting with a single thing is to add something to or take away something from the subject, and measure the difference. In order, the process includes: (1) measuring and recording conditions before changes are made; (2) making the changes; (3) measuring and recording conditions after the changes; (4) the calculation of the difference between (1) and (3); and (5) estimating the significance of the differences. Like measurements are also taken of a similar subject, but no changes are made in it. It is called the control.

When a group of subjects is used, several things have something added to them or taken away from them. Measurements are taken in the beginning and at the end, and the significance of any differences calculated. Instead of applying one factor to the experimental group, two equivalent groups may be selected. To one is applied one factor, to the equivalent group is applied the contrasting factor. Thus an experimenter might praise one group of children and discourage another. Instead of using equivalent groups, he might experiment with one group in rotation — for example, feed white rats carbohydrate diet for three months, followed by balanced diet for three months. In either type of experiment, another group to which nothing is added and nothing is taken away should be measured. This is the control group.

Groups may be equated in several ways. Groups whose members are selected by chance presumably are equivalent.

One may do this by taking every fifth, tenth, twentieth, etc., of the total population, assigning alternately to Group I and Group II. A second way is to equate by measurement — equal height, equal weight, equal intelligence, equal reaction time, equal age, etc.; or by any number of traits. In learning experiments it is important to have equality in the experimental trait, i.e., handwriting, and equality in ability to progress.

Where uniform behavior on the part of the subjects in respect to the experimental factor is premised, there is no need of equating at all. Pasteur expected that all sheep would respond uniformly to vaccine and to the virus of anthrax. He did not need to equate the two groups on the basis of age, weight, sex, breed, nutrition, etc. Had the anthrax inoculation been less deadly a skeptic would have argued, "something besides vaccine protects animals from anthrax." Had the vaccine been impotent a skeptic would have argued, "Vaccine is inadequate to protect animals from anthrax." It is somewhat risky to venture into so important an experiment without well-controlled conditions.

The rotation of subjects. Under many circumstances, an experiment performed on the same group, under rotating conditions, is advisable. The performance or the effect on each individual can be measured, first, under ordinary conditions; second, under experimental conditions *Alpha*, and third, under experimental conditions *Beta*; returning if need be to either situation at choice. This scheme is often adopted in feeding experiments to discover the effect of an item of diet, or the effect of lack of it. In a second cycle,

Beta conditions can be tested first, to be followed by the Alpha situation.

A brief description of a college teaching experiment may be used for illustration. The purpose was to discover whether the lecture method or the problem method is better. A standard course was worked out for the subject, and two equivalent test forms, *A* and *B*, prepared to measure results. The class was divided by chance methods into Groups I and II. On the first day, Group I was tested with Form *A*, Group II with Form *B*. The class was then taught the entire course in six weeks by the lecture method. At the end of six weeks, Group I was tested with Form *B plus* Form *C*; Group II was tested with Form *A plus* Form *C*.

Through the second six weeks the problem method was used. At the end of the period, Group I was tested with Form *A plus* Form *C plus* Form *D* (*D* being the equivalent of *C*); Group II was tested with Form *B plus* Form *C plus* Form *D*. The next quarter, the problem method was taught first, the lecture method second. The same testing program was followed. The results in terms of progress were calculated and expressed as a ratio between learning by the lecture method and learning by the problem method.

Two controls were used. First, a group was given the tests that did not take the course at all. The reason for this check was to measure whether growth or the passing of time added to learning in the field, rather than teaching. Second, a group was permitted to study independently. After the close of the experimental period, a class was taught by the method adopted as standard, using the same tests used in the experiment, the purpose being to verify the conclusions

as to progress. The usual question involved in verification studies was asked here: "Will it work?"

Laboratory experiment. A well-recognized rule of experimentation is to the effect that the experiment must duplicate all the conditions which are essential in the process being tested. This is as far as one need to go, however. He need duplicate *only* the essentials; it is not conducive to economy, accuracy in observation, and control to do more. Pasteur did not need to build a large sized brewery to carry on his studies of "sick" yeast. He was able to reproduce the essentials in his laboratory on a small scale. In the place of using sheep and cattle in vaccine experiments, it is more satisfactory to use guinea-pigs, white rats, and rabbits.

The experience of a graduate student may be cited to prove the advantage of putting experiments on a laboratory basis. He advanced the hypothesis that college teaching could be most successfully carried on by the vitaphone. He outlined a plan requiring the use of lectures, moving pictures, and the vitaphone. His estimate showed that the cost of the films which would have to be especially prepared for the experiment would run into several hundred thousands of dollars.

Such an outlay being impossible, he turned his attention to the analysis of the problem with the idea of reducing it to smaller proportions. His analysis showed three essential elements involved in vitaphone technique: the oral, visual, and dramatic. He perceived that he could reduce teaching in one situation to the oral only, in another to the visual only, but in the third he felt obliged to combine oral, visual

and dramatic (the last defined in simple fashion). The next step was taken when he perceived that the test could be made on individuals in the laboratory with a very simple equipment and a standard type of materials.

Laboratory experiments require apparatus. This term is loosely applied to signify instruments of precision, such as beakers, calipers, and footrules; and the things through which experimental situations are set up — batteries, keys, bell jars, pumps, inclined planes, retorts, tubes, rods, etc. Apparatus may be described as fundamental and accessory; fundamental in the sense that an experiment would be impossible without it; accessory in the sense that it is desirable but unnecessary. The study of a magnetic field requires a magnet; it is a piece of fundamental apparatus for this purpose.

Apparatus should duplicate only essential factors. This means that it should be simple, economical, and convenient. The great scientists have devised much of their apparatus; the rule may well be to follow their example, except where time and accuracy would be sacrificed by so doing. Standard instruments of precision should be adopted, and standard items of equipment, when they are available. The mistake should not be made of thinking that a great array of complicated and glittering paraphernalia signify a great scientist; nor should the fact be overlooked that great discoveries can be made with simple and inexpensive equipment.

Experimentation which has discovery for its objective should not be confused with laboratory exercises which have learning for their objective. A teacher may require his

students to perform laboratory exercises, by means of which important principles are derived, in substantially the same way in which they were discovered. The assumption underlying this type of teaching is that the principles are more vividly presented and more thoroughly understood. No discovery is made, however, and any verification by the student is entirely beside the point. The assumption also is that one working by the laboratory method will develop the habit of testing generalizations, and will learn to seek facts and principles by the experimental method.

Negative results. As has been stated, the experimenter often tests out an hypothesis without discovering more than the bare fact that his assumption does not hold. He may fail either to substantiate it or to refute it. Bernard[6] records a case that has application here. He performed an experiment in which he obtained positive results at the first trial. He repeated the experiment ten or twelve times thereafter without results. He did not think of denying the positive experiment in favor of the negative experiments, yet had he obtained the negative facts first he probably would have surrendered his hypothesis, for he concludes: "Negative facts when considered alone never teach us anything."

A thesis cannot be made out of negative results. An experimenter assumes that goiter is due to a protozoid. He conducts experiments without verifying his assumption. Suppose he proves that it is not due to a protozoid. He has no body of material for a thesis. He advances the hypothesis that teaching ability is positively associated with salary, training, and experience. He finds that it is not. He has no

[6] Claude Bernard. *Experimental Medicine*, pp. 173–74.

body of material for a thesis. To make a thesis, one must have positive proof.

The investigator should not mistake negative correlations for negative results. The only question that arises is whether the correlation obtained is significant. It is usually interpreted as significant if it is three times or more its probable error. The nearer it approaches unity the more significant it usually is. A negative correlation of .60 is as significant as a positive correlation of .60, if both have the same probable error. Only a zero correlation, or one so low as to lack significance, is to be interpreted as negative results.

Experimental record. Every step in the experimental procedure should be recorded, and every fact should be dated and labeled. Records should be as complete as they would be if the experimenter knew they were to be filed away for several years before tabulation; as complete as if they were to be worked up by another person than the one who gathered them. Some one may want to do this very thing; some one may want to take up the experiment where the first worker left off. He cannot do this unless the record is accurate and complete and the data well identified.

Kline[7] says that it will be advantageous, in the long run, if the first draft of the record and report is the *best* as well as the *last*. The habit of re-writing leads to inaccuracies in the first draft. Since a large amount of the attention of the experimenter must be given to the prevention and elimination of error, cautions, directions, and prescribed forms should be accepted and obeyed. An outline of an approved record form is as follows:

[7] L. W. Kline and Frances L. Kline. *Psychology by Experiment*, p. 8.

1. General field or topic of the experiment.
2. Hypothesis.
3. Subjects.
4. Apparatus described and drawn.
5. Procedure.
6. Data.
7. Results in form of generalization.
8. Relation to general field or to general theory.

The report itself should be in that form of prose known as scientific description (usually called exposition by the rhetorician). The terminology should be definite and complete to the extent that another can duplicate the experiment without asking for further explanation or information. As with Chaucer's Clerk of Oxenford, not a word more than is needed should be written. There should be no claims and no prescriptions. For models in conciseness, care, and modesty of report, nothing can excel the writings of Mendel and Koch; for brilliance in style, Spallanzani, Pasteur, and Lyell; for simplicity, Franklin and Faraday; for breadth of view, Darwin. One who writes to reveal truth about which he is enthusiastic has little need of rules of composition.

Summary. Experiment is largely depended upon in the natural sciences for the discovery of truth. It begins with hypothesis, and ends with law. A new law is discovered by the process called induction. Experiments are of two kinds — natural and controlled. Only the second type is usually adequate for thesis making. Five canons of experiment are given by Mill. One, the method of difference, is the chief method used. An important rule is to vary only one factor at a time. This is called the essential factor. Whatever is changed in the experiment is called the subject. Often

subjects are treated in groups; often the groups must be equated. An attempt should be made to reduce an experiment to laboratory control. Negative results are not acceptable as theses.

QUESTIONS AND EXERCISES

1. State an hypothesis which should be investigated by experimental means, and outline a tentative plan to test its truth.
2. Find out how Pasteur discovered that germs cause disease. How Reed discovered that mosquitoes communicate yellow fever. How Theobald Smith discovered how ticks communicate Texas fever.
3. Distinguish between Mendel's Law and Gresham's Law as expressions of scientific knowledge.
4. Distinguish between a natural experiment and an artificial or controlled experiment.
5. List a few common beliefs and opinions. Can any of these be subjected to the test of experiment? Explain.
6. Why can history not be regarded as an experimental science? Does the fact that it is not an experimental science preclude it from being classed as a science? Discuss.
7. Study one of the important experiments and report upon the procedures. Typical scientists to consult are Faraday, Koch, Reed, Pasteur, Kelvin, Gilbert, and Bernard.
8. Show why analysis of a situation into antecedents is necessary before an experiment can be conducted.
9. Study the experiments performed by Theobald Smith to find how Texas fever is communicated. Point out any of Mill's canons of method which he used.
10. Define the term *subject* as it is used in experimentation. Define apparatus. Can instruments of precision be properly called apparatus? Discuss.
11. Show how the formula for partial correlation can be used to function in much the same way as experimentation.
12. What is meant by negative results? Should a thesis be accepted in which the results are negative? Explain.

PROBLEM 11

Setting up an Experiment

Situation 11: The Central City high school enrolls 2500 students. It is a four-year school, offering the following courses in science: general science, biology, botany, zoölogy, physiology, physics, chemistry, and agriculture. The laboratories are average in the biological sciences; in the other sciences quite superior.

The head of the department has not been satisfied with the results being obtained. The results obtained on achievement tests reveal that the school is about average, but the range of abilities is wide, and some pupils seem to make little or no progress. He declares also that they do not acquire ability to perform a laboratory experiment, and that they are not scientific even to an average degree in attitude.

He proposes, therefore, that the demonstration method be substituted for the laboratory method, lectures and all other types of work to be continued as before. He says he is convinced the students will make more rapid progress where the teacher performs the experiment before them (demonstration) than where they set up the experiments and perform them themselves.

When this matter was discussed, in a department meeting, a difference of opinion appeared. Several of the teachers were strong in their opinion that the laboratory method is better. Another said that neither the laboratory nor the demonstration methods were best, but instead that the teacher should use what he termed an *eclectic method*, in which lecture, discussion, demonstration, experiment, etc., all appeared.

There being no possibility of agreement, when the proposition was made that the question be submitted to experiment it was readily accepted. The question then arose as to procedure; strangely enough, a question of some perplexity even to a group trained in science and engaged in its teaching.

Problem 11–A: What kind of experimental set-up is advisable in order to test out the relative merits of the demonstration and the laboratory methods?

Problem 11–B. What extension of the experiment is necessary to discover whether the eclectic method is better than either demonstration or laboratory?

Special questions:

1. Is it safe to assume that this is a typical high school, and that intelligence ranges from very low to high, with a mean of about 100 intelligence quotient?
2. Is it possible to take account of all possible values that may be realized through the contrasted methods? Is it better to see under which method the children acquire the most knowledge before testing for other values?

Bibliographical note: See Selected References: Avey, Albert E.; McCall, W. A.; and Rusk, Robert R. This problem has been tried out a number of times without very conclusive results. For procedure, see the original investigations by consulting references in texts on the teaching of science, and the *Reader's Guide.*

PROBLEM 12

Correlation versus Experiment

Situation 12: A problem of great importance to all teachers, students, and patrons is: "What is the largest number of children that can be taught successfully in a class?"

This question is causing great concern in the Eldorado high school. In a recent survey, it was found that there were 140 classes being taught daily; that the smallest class enrolled 2 pupils, the largest enrolled 65. The median class had 13 pupils; three fourths of the classes enrolled fewer than 30 pupils. Obviously, the school had no standard of best class size.

The new school board, recently elected, takes the attitude that the teachers might as well instruct 30 pupils in a class as 10. If the larger standard were adopted, the board could conduct the school for a smaller amount of money. The teachers, for the most part, believe that the small classes are superior; the patrons are divided in their judgment.

When an attempt was made to secure advice from competent authorities it was discovered there was no agreement. City superintendents favored classes of thirty, teachers classes of twenty, and critic teachers classes of fifteen.

The survey staff have data on this school, and on other representative high schools, covering the following:

1. Achievement scores in the leading high-school subjects.
2. Intelligence-test scores.
3. Age and grade in school, and size of class in which enrolled.
4. Number of days in attendance at high school.
5. Marks given by the teachers.

There are some who believe that the only way the question of larger or smaller classes can be settled is by conducting an experiment. Others declare that the correlation method can be applied to the data of the type indicated above, and the relative weight to give to classes of different sizes calculated.

Problem 12: How should this problem be solved? Is experiment essential, or can a correlation technique be applied?

Special questions:

1. Was there any value in obtaining the opinions of superintendents, teachers, and critics on this question?
2. Why consider the correlation method at all?
3. Would results from an experiment, in which only the pupils in this school participated, be conclusive?
4. Would a skeptical person accept the results of the correlation study as final? Would he insist upon an experiment?
5. If experiment is inevitable in order to settle the question, why consider a substitute of any sort?

Bibliographical note: For references on the experiment, see Selected References: Bernard, Claude; Cooley, W. F.; Jevons, W. S.; Kline, L. W., and Frances L.; and Mills, John; and consult Selected References for Chapter V: Brown, William, and Thompson, G. H.; Kelley, T. L., *Statistical Methods*; Rietz, Henry L.; and Yule, G. Udny, for references on statistical method.

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CHAPTER VII

THE HISTORICAL METHOD

1. *Field and sources*

Meaning of history. *History* is derived from a Greek term which means learning or knowing by inquiry. The historian was one who engaged in search after knowledge, no matter what the field of his inquiry. Later, the word came to be applied to what had been learned or discovered, particularly when the results were put into manuscript or printed form. A common use of history is to signify the whole series of happenings in the world, or in any political division of it. World history, Greek history, Roman history, illustrate this meaning. The idea seems to be that the events were real objective things with which the historian might compare the written records, and by which the records may be verified. Needless to say, nothing of this kind can be done, and *history* should be confined to the scientific description (narration) of the past as it is found in documents.

The true meaning of history can be seen better by comparing it as a science with experimental and normative sciences. In experimental science the observer controls the factors, and therefore controls the events; in normative science the observer evaluates the events, and develops the means of predicting their occurrence. While he cannot always control normative events in the future, he can at least take advantage of his prior knowledge of what is going to

happen. In historical science, the observer neither controls nor evaluates. His whole concern is to report what he observes with accuracy and fidelity, leaving to the philosopher, or whoever pleases, the task of passing judgment upon whether the events were good or bad, high or low, superior or inferior. Having no responsibility for the events and exercising no control over them, he can take a wholly dispassionate and impartial attitude.

Not everything that passes for history is scientific history. Herodotus wrote history, but the result was a curious mixture of fact, legend, unverified hearsay, guess, and opinion. Thucydides was the first historian in a real sense. He set himself to present "an accurate knowledge of what has happened." "I have not presumed," he said, "to describe them (events) from casual narratives or my own conjectures, but either from certainty, where I myself was a spectator, or from the most exact information I have been able to collect from others." A textbook is not history; it is at best an outline of history. A great collection of source materials is not history. Only an "accurate knowledge of what has happened" meets the requirements of the history thesis.

Fields of historical science. Although history ordinarily signifies the story of mankind, as a science it has a far wider range. It includes natural events as well. The method of arriving at truth in law is almost purely a method of historical science. Genetic studies in zoölogy, botany, sociology, political science, education, biology, and psychology are complete illustrations of the application of historical method. Geology is the history of the earth. Wherever scholars go to origins and trace developments, they are pro-

ducing history. Perhaps rightly enough, the history of mankind has come to occupy the most prominent place, a fact which explains why it arises in our associations when history is mentioned.

Not only are there many fields which use the historical method and whose product may be called history, but many branches of learning supply sources for historical research. One may write a history of physics, of chemistry, or of business. Courses are taught in the history of science, the history of education, the history of psychology, the history of literature, the history of economic thought, and there is also the history of history. Therefore, the historical method has a place in all the fields of knowledge.

Sources of history. Since the historian cannot create sources, he is dependent upon what he can find. The geologist studies the effects of natural events, but human history is based upon the effects of human events. The sum total of sources may be given the name of "records," which may be subdivided into *remains* and *written documents*. Remains are relics of man's activity which have come down from past ages, without conscious intention on the part of any one to impart information. Examples are arrow heads, pottery, coins, vases, horn cups, battle-axes, gravestones, boundary markers, and the dozens of fragments of tools and utensils which have been preserved in caves, burial mounds, and kitchen middens.

Written documents are a type of record which have consciously been prepared for the purpose of transmitting information down through the years. The medium may be stone, clay, papyrus, parchment, glass, or paper, but in all

cases the vital point is the purpose to impart information to succeeding generations. Census rolls, patent office records, military records, wills, deeds, court records, preambles to statutes and constitutions — all are examples of written documents. A relic marked with a date or the name of a ruler passes into the document class; a bridge, a palace, an unmarked monument may be merely remains of the special type called memorials.

Documents may be classified also as official and non-official. Proceedings of legislature and cabinets, reports of public officers, and records of public transactions are official records. Newspapers, diaries, autobiographies, personal letters, ballads, tales, memoirs, paintings, annals, chronicles, and certain classes of inscriptions are non-official. Within limits, these classifications reveal the value of sources, remains being of least value, non-official documents next, and official documents most valuable. The limits apply mainly to authenticity or validity; a true non-official document is superior to a non-valid or partly valid official document. The test of value is therefore not the class to which the source belongs, but its validity and reliability.

Scientific history cannot be derived from remains, because it is impossible to produce an orderly series of events from them. Remains are fragmentary; gaps exist in their description. If the gaps are filled in by the historian, something not true (not derived from research) has been added, which vitiates the entire history. If gaps remain there is a lack of coherence — an essential to science. For this reason, the days before written documents are called pre-historic. The dawn of history dates from writing. A knowledge of the

setting of an historical event may aid the historian in interpreting the results of his research, or in checking the reliability of his witnesses, but topography, heights, fortifications, barrows, mounds, bridges, roads, buildings, and monuments are not consequently to be looked upon as real sources of historical data.

In *The Advancement of Learning*, Francis Bacon distinguishes between "perfect" histories, and "imperfect" histories. He declares there are two types of imperfect histories: (1) those based upon memorials, and (2) those based upon antiquities. The antiquities of history are "monuments, names, words, proverbs, traditions, private records and evidences, fragments of stories, passages of books that concern not story, and the like." Memorials are "commentaries which set down a continuance of the naked events and actions, without the motives or designs, the counsels, the speeches, the pretexts, the occasions, and other passages of action," and also registers — "collections of public acts, as decrees of council, judicial proceedings, declarations and letters of state, orations, and the like, without a perfect continuance or contexture of the thread of the narrative." This not only points out that remains are an inadequate source of history, but shows that a mere tabulation of data does not make "perfect" history, which is but saying that history is like any other science.

Sources are sometimes classified as original and secondary. Original sources are the records made by actual witnesses of the events, or the direct testimony of these witnesses by word of mouth. A thesis cannot be written from secondary sources, because it would be neither original nor a contribu-

tion. One would simply be appropriating the work of another as much as if he had taken his tables of experimental data or his norms. Moreover, it is not research, since there is no scientific process required. Secondary sources may be read to give background, point of view, and familiarity with technique, but they have nothing to add to the store of fact on which the truth of the thesis rests.

Validity of sources. The first step in historical research is to establish the validity of the sources. This process is called historical criticism, but in purpose it does not differ from the establishing of validity in the normative sciences. The question to be answered is, "Are the sources what they purport to be?" This document purports to be Pinckney's plan for a constitution of the United Colonies. To prove, beyond reasonable doubt, that it is Pinckney's plan is the object of what is known as higher criticism. To discover the context of the original is the work of lower criticism. This means the filling in of omissions, and the deleting of additions. Lower criticism is so called because without it higher criticism is of no avail. "Lower" is used in the sense of foundational: higher stands for the superstructure reared upon the basis built for it.

One of the leading requirements for historical criticism is ability to read. This is easy enough if the document is plainly printed or written in English. Even if it is in English, but written in a poor hand, containing words long obsolete and words whose meanings have greatly changed, it may be hard to decipher. If to these difficulties, one adds faded ink, stained paper, a foreign language written by one who knew it imperfectly, the task of lower criticism be-

comes a real test of ability. Knowledge of many languages may be required: Chaldee, Hebrew, and Syriac; Latin and Greek; French, Spanish, Italian, and German. The chief thing to realize is that language is the key which unlocks the historical documents; one cannot engage in historical research without the key or the keys.

The scientist engaged in establishing a norm relies upon a criterion to establish the validity of his facts. As has been seen, the criterion may be expert judgment. The historian also depends upon the expert to establish correct texts, separate the true from the false, find the date of manuscripts, and locate inscriptions. Great numbers of documents have been collected and edited, and made available to the student of history. This work has usually been financed by governments, and by our own political states, frequently under the direction or supervision of historical associations. Seldom does the graduate student writing a thesis in history have any more serious task in lower criticism than is involved in supplying a word or checking a copy of a document against the original.

He should, nevertheless, appreciate the patient, protracted, highly specialized labors of the many who have made his own work easier and more valuable. To the palæographer, the specialist in handwriting, he owes thanks for many manuscripts which, unidentified, undated, and unread, would have remained closed to him. To the epigrapher, he is indebted for inscriptions gathered from all parts of the world. To the diplomatist, he gives credit for aid in validating decrees, ordinances, charters, and constitutions — a task which calls for special knowledge of methods of drafting, signing, sealing, and attesting official papers.

Higher criticism takes up the date, authorship, contents, and purpose of the documents. The date is important in connection with validation, because it permits the historian to apply tests of its truth. If the document contains terms and references not in existence at the date it is purported to have been written, there is no doubt of its being a forgery. The authorship must be known, in order that one may form an estimate of the possibility of his having produced the work. The content carries within itself evidences of its truth or falsity, while knowledge of the purpose of the manuscript serves as another check against the date, the writer, and the content. Moreover, without such information, one would find great difficulty in estimating the reliability of the document.

Reliability of the sources. The second question for the historian to answer is: "Are the sources reliable?" "There is no doubt," a critic may say, "that this document is what it purports to be, but is the writer telling the truth?" If one were developing a norm, he would answer the question of reliability by pointing out the correlation between the two forms of his measuring instrument, or between two forms made of the chance halves of the same instrument. In historical research, however, there is as yet no known method by which the investigator can express mathematically the reliability of his witness. He is forced to express a judgment.

The situation is much the same as confronts a judge in a court of law. He is, first of all, only desirous of knowing the truth. His concern is over whether the witness is dependable, and whether he was in a position to know the truth.

Before considering the testimony he asks, "Is the witness reliable? Does he tell the truth? Was the situation of the witness such that he had an opportunity to know the events? Is his ability such that he would be aware of the events that transpired?"

His honesty turns upon such statements as these: (1) he is not prejudiced in any way, (2) his religious or political passions do not enter into the case, (3) he has nothing to gain by falsifying, and (4) he has a reputation for telling the truth. His ability may be established by showing that: (1) he is in command of all his faculties, (2) his senses are keen, (3) he was where the events transpired or in a favorable position to know them, and (4) he has had special experience and training which equips him for rendering a true report.

Once the honesty and ability of the witness has been proved, the point of interest shifts to his testimony. The two chief questions are: (1) is the testimony reasonable? and (2) does it agree within itself and with other evidence? Testimony of a nature that transcends human experience would be doubted because it is not reasonable. There was a time when miraculous and magical tales would obtain credence, but the historian is not deceived by such testimony. A witness who told of seeing a ghost in the king's chamber might be accepted as honest, but his intelligence or sanity would be in doubt. A witness who testified to an exhibition of supernatural powers on the part of an old woman accused of witchcraft would impeach his own character. Before any testimony can be accepted the presumption must be granted, or demonstrated, that *the event could have happened as described.*

The testimony must be free from conflicts within itself. If, in one place, the witness declares the event took place on the Fourth of July, 1776, and in another sets it two months ahead, what is one to believe? While such a difference does not convict the witness of deliberate falsehood, while a minor error in memory or of writing may explain the disagreement, while even the actual occurrence of the event is not necessarily brought into doubt, yet the multiplication of such conflicting statements throughout the manuscript would cause one to regard it as unreliable. More value is ascribed to a manuscript if it agrees in essentials with other authorities accepted as dependable. Agreement is in fact the ultimate test of reliability of anything. Experimental results that agree with standard results constitute a reliable experiment; a test that agrees with a reliable test is itself reliable. Testimony that agrees with reliable testimony is dependable. Mere agreement does not satisfy, since all of those rendering the testimony might indeed be liars; in the final analysis the reliability of historical authority must go back to the honesty and capability of the witness. The testimony of one honest and able man is worth more than the testimony of all the incapable rogues in New York.

Error in history. Authorities, however, may be equally honest and capable and still disagree. If the historian finds this to be the case, and if he cannot produce additional witnesses or indirect evidence on one side or the other, he is in the position of an experimenter who obtains negative results from his experiment, or of the deviser of norms who fails to develop a sufficiently accurate test. Occasionally, the conflict is more apparent than real; it may be due to

different points of observation. The historian is not warranted in assuming any such explanation; he must be able to prove it. Unable to reconcile his authorities, the only recourse is to choose a new subject, or to discover new sources that will tip the balance and perhaps reveal the cause of the disagreement.

There still remains a possible source of error in history. This may be traced to the historian himself. The makers of the sources are not historians; they may have done their work of recording what they have observed, and yet the history may be distorted and untrue because of the liberties taken by the writer. This is not a danger which belongs to history alone; the experimenter may omit something true and add something untrue. The experimenter, though, is assumed to be protected to some degree at least from the temptation to present false data because he is guided by a technique that makes any manipulation easy to detect, and because his feelings are not likely to be enlisted either in the welfare of his subjects or in the outcome of the experiment. In contrast, critics point out the subjective character of the historian's work, his lack of an objective criterion, and the probability that his emotions will be aroused to favor or oppose the person, group, cause, or movement with which he deals. Their religious prejudices are his, he belongs to their political party, he supports the legislative program they favor. Inevitably then, it is claimed that what he finds and reports will be colored by his feelings.

Such considerations have led certain writers to cast a doubt over the truthfulness of any history. Carlyle referred to it as the great Mississippi of falsehood; another speaks of

it as a fable upon which there is agreement. Such harsh comments are undeserved. The historian who selects all the sources, who subjects them to criticism after the approved tenets, who checks the testimony of one witness against the testimony of the others, who records all the facts of his subject faithfully, who reports his facts accurately, and who makes reasonable generalizations on the basis of his facts, runs no more risks of emotional upset than his fellows in experimental and normative science. A charter certainly seems no more stimulating to the emotions than a deadly bacterium, or than the intelligence quotient of a beautiful moron. Anticipations of disaster grow out of fears, from which, it seems, critics are not exempt. Any historical study may be verified in the same way a norm or an experiment may be verified — by another investigator going through the process and comparing his results with the results already obtained. In this way, no one is likely to be imposed upon very long by deliberate falsehood.

Because this optimistic view is taken, one should not be accused of maintaining that history is absolute truth. Like the measurements of the physicist, the historian produces approximate truth, best expressed as *probable truth.* Underlying historical generalization is the theory of probability, applied, not in looking forward as in the predictive sciences, by means of a statement that such and such an event will probably occur, but by looking backward with the generalization that such and such an event probably occurred. Probability in history looks backward; probability in the other sciences looks forward.

Mathematically speaking, probability is the ratio between

the factors favorable to an event and the total number of factors involved, favorable and unfavorable. It is expressed in the formula

$$P = \frac{p}{p + p'}$$

in which P = probability of an event being true, p = the number of favorable factors, and $p + p'$ the total number of factors (sum of the favorable and unfavorable). For example, if there are 20 favorable factors, and 5 unfavorable,

$$P = \frac{20}{20 + 5} = 80,$$

which may be read 80 per cent, or that there are 80 chances out of a hundred that the report is true.

When the value of the probability ratio is 100, the result is certainty; when it is 50, it is uncertainty; when it is 0, it is impossibility. Such a result (zero) means that $p = 0$; there are no factors favorable. As a matter of fact, in much historical work, though absolute certainty is not reached, there are some favorable factors. Technically, the ratio, however small, expresses the probability of the event having occurred. For example, if there are 5 favorable factors, and 20 unfavorable,

$$P = \frac{5}{20 + 5} = 20,$$

which is read that there are 20 chances out of a hundred that the event occurred. Interpreted, this means that it is improbable that the event occurred. If the number of favorable factors are more than half of all the factors, the

results are positive, and the more closely the ratio approaches 100, the greater the likelihood of truth. Lacking numerical data, the actual probability coefficient cannot be calculated, but an understanding of the principle underlying historical truth will aid the student in judging events and the product of his effort.

Hypothesis in history. The position has been rather consistently maintained that research cannot begin until a working hypothesis has been formed to guide effort. This seems to be readily admitted so far as experimental and normative sciences are concerned, but some historians are loath to admit an hypothesis as essential in historical research. They regard an hypothesis as a prejudgment, or commitment, when the mind should be kept perfectly balanced and open for the reception of facts. All experience, however, demonstrates that gathering facts without direction is but blind groping, searching in a fog; an activity in which one's success or failure is determined by chance and not by his historical ability.

Other reasons for discarding this timid and tender-minded attitude are to be found. First, the example of other scientists should count for something. Certainly no one can seriously maintain that scientists are less accurate and less prone to prejudices and predilections which vitiate their results than the historian. Second, no one who has the ability to engage in real research can divest himself of all preconceptions. As Johnson says, "The historian who thinks that he can clean his mind, as he would a slate with a wet sponge, is ignorant of the simplest facts of mental life." [1]

[1] Allen Johnson. *The Historian and Historical Evidence*, p. 160.

The objection of the historian seems to be, not to working hypotheses, but to fixed theories that control investigation. They are familiar with the havoc wrought to truth by an investigator laboring under the burden of the economic theory — the great-man theory, the manifest-destiny theory, the institutional theory. Such persons apparently are not interested in the whole truth, but they select or trim their facts to establish their general notion. Fact which favors their theory is given a conspicuous place; fact which opposes it is discarded or ridiculed. Deriving their generalizations from mass data, they next proceed to apply their principles to individuals, forgetting that while the principle may be true of great numbers, it may still be utterly useless as a means of individual diagnosis. Historians are right in refusing to acknowledge either the methods or the results as scientific.

The frontier-theory of American history exemplifies the danger of accepting a general doctrine not emerging from facts. Engagingly stated, it became shibboleth in the minds of scores of eager young historians, who tested their facts and the unity of their description by its form. The obvious significance of the law of probability was overlooked, and coefficients no higher than 51 to 60 were accepted as signifying absolute truth. One hundred thousand votes were cast for a candidate favoring the gold standard; ninety-five thousand votes were cast against the candidate and in favor of free silver. Gold-standard votes were cast chiefly in urban areas; free-silver votes in rural areas. "What could the results signify," the historian asked, "except the overpowering influence of economics, represented on the one hand by the frontiersmen, and on the other by the urban

laborers and capitalists?" How could the frontier influence shape the votes of nearly half the total and leave unaffected the remainder? Certainly its effect was not uniform, and the variability indicates the presence of many factors acting upon each voter. Considering the frontier doctrine, alone, the evidence is beginning to point to its inconclusiveness: the facts are not in accord with it. If climate, soil, topography are potent factors in shaping the actions of men, they could not well produce variability in the same area. since they are relatively constant factors — they influence all alike.

The historian is not limited to the consideration of a single hypothesis. As in experimental science, he should have little difficulty in stating many assumptions, any of which may prove to be true. His task is to analyze the whole situation as early as possible and to list all of the hypotheses that result. When beginning his research, he tests the assumption that seems most plausible, but if it is untrue he rejects it for another. Some stretch of the imagination is required to understand how an intelligent investigator would continue in his faith in a proposition which has played him false, when he has the free choice of trying another that may prove respectable. Such an assumption is on a par with the supposition that a man prefers a dishonest and treacherous wife to a true one.

2. *The writing of history*

The research process. After the authenticity and pertinence of the sources has been established and an hypothesis formed, the work of collecting data begins. This consists in

taking down extracts from the sources. The general principle to guide one in taking notes is this: Copy facts tending to show the truth and the falsity of the hypothesis. The amount which should be copied is no more and no less than is needed to reveal the testimony. When the note-taking process is completed, the investigator will have at hand several hundred notes or separate items of data, not differing in any essential respect from the record of the experimenter and the tables of the normative scientist. Each fact will have attested upon the same sheet its source and the actual place in the source where it was found. In order to avoid confusion and error in transcribing, arranging, and verifying, only one item or note should appear on a sheet.

When all of the notes have been assembled, they should be checked against the sources to prove that they are accurately quoted, the name of the witness correctly written, and the page of the reference exact. All of the notes should next be arranged in the order in which they will be used, which normally means that they will be arranged in time order. For convenience in handling the notes and writing the report, as well as for ease of reading, the notes may be divided into groups that fit in with the plan of the narrative and the natural divisions of the subject. One section of the notes may be those which take up the connection with what has gone before, another with the initial period or origin, another with a later stage of development, until the last is reached which properly comprises the dénouement and resolution of the whole matter. This stage of history making is well described by Fling: [2]

[2] Fred M. Fling. *The Writing of History*, pp. 139–40.

In the treatment of a sub-series, the facts of the series should be arranged in chronological order for study, in order to determine the number of main groups into which the series should be divided. As, for example, in dealing with the work of the French national assembly in making a constitution, we would first have the creation of a first committee and its report, the creation of a second committee and its report, the declaration of rights, the foundations of the constitution, the division of France into departments and districts, and the creation of municipalities. Each of these heads in turn would become a main head under which the facts would be grouped, and this subdivision would be followed until we reach the single undivided fact.

In outline form, these divisions would appear as follows·

I. Creation of the first committee and its report.
II. Creation of the second committee and its report.
III. The declaration of rights.
IV. The foundations of the constitution.
V. The division of France into departments, districts, and municipalities.

Suppose, however, two series of events occur at the same time. Continuing the discussion of Professor Fling:

For example, before the legislation on departmental organization was completed, the assembly began the consideration of municipal organization and up to the end of December, 1789, both subjects occupied the attention of the assembly. Here the rational course is to make two sub-series, following the debates on each to the end, that is, to the passing of the decrees creating departments and municipalities, then to combine these sub-series in the order (1) departments, (2) municipalities, and to incorporate them into the larger outline of political activities. This will necessitate some chronological overlapping, but that is inevitable in any good synthesis.[3]

Before taking up the actual writing, there should be considered *the scope of the thesis.* No one believes that an

[3] Fred M. Fling. *The Writing of History*, p. 140.

historical thesis can be prepared by arbitrarily marking off a period of time and saying that all the events occurring within that period should supply the content of the thesis. Such a description would lack unity and coherence; it would be little more than an unrelated and discordant jumble of facts. The answer may be made: (1) in terms of the hypothesis, and (2) in terms of development or growth of the series of events. In terms of the hypothesis, the scope of the study begins at the origin of the movement, and continues until that time when the truth of the hypothesis has been proved, which means in terms of development or growth, from its genesis to its fruition. Any marked break or change in the series might well serve as a stopping place for the thesis, because it would signify a period in which a new association of causes had asserted themselves. From the first act to and through the climax, is a phrase which serves to limit the scope of an historical thesis.

In the narrative, itself, characters and events are brought forward as they play their parts on the stage. "This," says Vincent, "is the dramatic arrangement, and is simply the rule observed by the playwright who brings forward his characters when they have something to say which contributes to the development of the plot." [4]

Historical composition. Following the organization, comes the actual writing. Historical discourse is called narrative because it presents a story in time order, but the term scientific description, which has been applied to reports of experimental and normative research, is equally appropriate. The purpose of the writer is to show what was done and

[4] John M. Vincent. *Historical Research*, p. 296.

what happened. In narrative, the idea of maintaining the story interest may take precedent over the desire to express the actual facts, and no more. Scientific description is the technical term for all kinds of truly scientific writing. It means accurate presentation of the results of research.

Professor Fling believes that the historian should make clear three things: (1) the original condition, (2) the action, and (3) the novelty in the resulting conditions.[5] The account should be written with due care for accuracy and completeness, but with no attempt to secure literary effect. If the data are dramatic they should be presented dramatically, but seldom does an historical treatise take the form of a perfect drama, with all the unities intact. The historian can write no more interestingly than the events; to criticize an historical thesis because it does not read like a novel is like criticizing a report of an experiment because it is not a masterpiece of humor. No anxiety for the reader should be felt; the sole object should be to give the truth. If one happens to have a happy and felicitous style of expression, there is of course no reason why he should not apply it as far as he can to history writing.

As much source material as can be should be incorporated in the text. When the historian speaks, he speaks in the words of his witness. There are two reasons for quoting: (1) the account is more vivid, and (2) the account is more true. No rule can be laid down that will fix the amount to quote: the smoothness of the description, the importance of the witness, the number of other witnesses to be reported — all are points to consider. The quotations are given, the

[5] *Op. cit.*, p. 150.

writer should remember, not for illustration, as in essay writing, but as proof or evidence. Where the witness offers no summarizing statement of his own, the writer may often condense facts into a single general statement, just as a scientist in other fields may use a few measures to express all the facts in an array of data. The chief rule then is: quote the witness when his words are clear, condensed, and to the point. When the witness is discursive, ambiguous, and fails to summarize, then the historian should generalize the facts as clearly and briefly as is possible.

Footnotes are an essential part of historical writing. Fling[6] designates three kinds of footnotes: (1) citations to volume and page where the evidence is to be found, (2) quotations from the source in the exact language of the source, and (3) remarks by the writer on the pertinence, reliability, or validity of the evidence upon which some statement has been based. The citation should be exact enough to enable the investigator to find the reference instantly, once the source is in his hands; it should either be complete enough to enable him to obtain it from the library without further information than the call number, or it should be supplemented by such a complete form in the bibliography.

A carefully arranged list of sources should follow the thesis proper. The primary sources should be kept separate in the bibliography from any secondary sources listed. They should be arranged in alphabetical order according to author, or in chronological order. They should be grouped according to type, as diaries, correspondence, newspapers,

[6] *Op. cit.*, p. 171.

official documents, etc. A critical note concerning each group and each source of importance, indicating what the nature of the material is and how reliable it is, should be appended. Unpublished sources and any long critical discussions belong in an Appendix. An historical thesis, when carefully arranged from table of contents to appendix, and clearly written, affords not only a measure of research ability but of scholarship.

Results in history. The closing pages of the thesis proper is the place for any generalizations. In the main, these are a reiteration of the hypothesis, which is declared to be true, as proved. The result of experimental research is a law; of normative research a norm; of historical research the result is a verdict of truth. Only positive results constitute a contribution.

Authorities on historiography commonly assume the necessity of the historian's establishing a cause-and-effect relationship among his events. The ideal arrangement seems to be one in which cause *a* results in effect *b*, and *b* causes *c*, and so on, perhaps in growing momentum until the climax in an epoch-making effect is reached. So complicated, however, is the pattern of human behavior that to unravel it until each strand is distinguished from every other is a superhuman task. Multiple causes are playing upon the individual all the time. The weight of each is usually unknown because as yet unmeasured. Nearly two thousand simple habits make up the complex called skill in arithmetic; a thousand or more inhibitions have been identified, each with its appropriate nervous and muscular system. How can an historian say that this or that ex-

perience was the cause of a king's edict; or this or that alone caused the mob to march upon the palace? Pearson's conclusion that association should be searched for rather than causation seems to apply with as much force to history as to any other science.

The task of the investigator in history is considerably simplified if he is absolved from the duty of finding causal connections and from evaluating the act of his characters. After making these concessions, in the interest of scientific precision, should the historian make connections between his verdict and the general theory of history? Should he show that his findings corroborate and belong within the great-man theory, the economic theory, the environmental theory, the spiritualistic theory, the anthropological theory, the sociological or institutional theory, the evolutionary theory? Is government, war, religion, education, industry, personality, climate, natural resources, or a combination of these the all and end-all of human action?

The old historians held largely to the theory of political causation; the self-designated new historians shout their faith in synthetic or "collective psychological" theory, a concept baffling to the scientific mind, but as all-inclusive and indefinite as Spencer's god.

This is not the place for pronouncements from the pulpit, but the conclusion must be that, while pure speculation may be entertaining, it does not belong in a work that makes serious pretension to science. History is no place for the naïve and now discredited fantasies of the psychoanalyst. Until advances have been made in individual and social psychology (not probable until the white-rat mania has spent

itself) the writer of the historical thesis will do well to consider his work finished. To him there is probably no better advice than that contained in a statement by Niebuhr: "In laying down the pen, we must be able to say, in the sight of God, 'I have not knowingly nor without earnest investigation written anything which is not true.'"

EXERCISES AND PROBLEMS

1. Do historiographers usually consider historical methods as basically different from general scientific method? Explain their position.
2. Trace briefly the development of historiography down to the present. What contribution to historical method has been made in this country?
3. Historians who participated in the controversies between Protestants and Catholics in the Reformation period were the first to cite their authorities, but chose only those witnesses who were favorable to their respective sides. Under such circumstances, were the citations of any value? Did they add to the reliability of the histories?
4. State the purposes of history. Does knowledge of the past help us to foresee the future? Discuss.
5. Assuming that a textbook in the History of the United States from 1789 to date covers the main events truly and accurately, is it or is it not scientific history? Discuss.
6. Discuss the *pros* and *cons* of the hypothesis in historical science.
7. Commencing with the search for historical sources, set down in order the chief steps in the historical process.
8. Is there any distinction to be made between the historian's passing judgment upon his witnesses, and upon the characters described by the witnesses? Discuss.
9. Can history be scientific if the historian's beliefs and standards are interjected into it? Explain.

10. From the research point of view, does the so-called new history differ in any way from the old history? Explain.
11. Show how an historian can use a criterion to establish the validity of his sources.
12. Enumerate as many factors as you can which might enter in to cause one to discredit a witness.
13. Show what to do when apparently equally reliable witnesses disagree in their testimony.
14. Explain how knowledge of the theory of probability may be useful to the historian.
15. State the chief theories of history. Show the origin of at least one. Is interpretation, in the form of connecting one's thesis with appropriate historical theory, a proper requirement? Why or why not?

PROBLEM 13

The Application of Historical Method

Situation 13: Two graduate students of the University of Carizona are perplexed about the limitations and applications of the historical method. The first chose, for his field of study, Court Decisions affecting the Practice of Medicine in the State of Carizona. He collected all the cases in the entire period of state history, and proceeded to classify and index them much after the method of legal digests. His thesis, however, was not accepted by the graduate council on the grounds: (1) that he had not done anything any stenographer could not do, (2) that his work had not resulted in a general principle or principles, (3) that he had not employed scientific method, and (4) that he had not made a contribution to knowledge. He was advised that he might have obtained a thesis had he treated his sources historically.

The second student chose to study The Development of Public Highways in States west of the Mississippi, particularly searching for factors causing and associated with the development. He depended upon public documents, statistical reports of various kinds, current matter, etc. He presented his results as running narrative, after the form of history. He differentiated important factors going along with road development, and described their

connection and influence. He was told that he was not using the historical method, but a genetic or survey method, and advised that if he wished to write history he should have confined himself to a narrower field: *i.e.*, the history of highway development in one State.

Both of these students wish to satisfy the requirements for the thesis with the materials with which they have been working, making any changes in form and any additions necessary.

Problem 13–A: What should the student working with the court decisions do?

Problem 13–B: What course should be followed by the second student?

Special questions:

1. What determines the method one should use in developing a thesis?
2. Is there any question of validity of data involved? Of reliability?
3. Can a thesis be derived by the mere process of classification?
4. In attempting to find the weight of various factors influencing highway development, is the second student really writing history? Can his results be called sociology?
5. Can the normative method be applied to either of these problems? The experimental? What method is left?

Bibliographical note:

These problems cannot be solved by reference to any books and articles known to the writer. Material bearing upon the problems is contained in the text. A careful reading of books and magazines treating historical method should be helpful.

PROBLEM 14

Is History a Science?

Situation 14: Miss Warren was given her preliminary examination for the doctorate last week. On account of the direction which the examination took, concerning her thesis, she is uncertain

whether to continue in history or not. The section of the examination, over which she is concerned, was as follows:

"In what field is your thesis?"

"History."

"Is history a science?"

"No."

"Why not?"

"One cannot predict what is going to happen from it."

"Is it your understanding that ability to predict is an essential characteristic of true science?"

"Yes."

"Why cannot one predict from history?"

"The events with which one deals are unique. They can never be exactly repeated — that is, in the ordinary course of affairs, they never will be repeated."

"This is to say, that x cannot be predicted from y?"

"Yes."

"What is the object of research?"

"To reveal truth."

"Must you produce a thesis by means of research in order to meet the requirement for the doctorate?"

"Yes; the thesis must be an original product."

"Are science and truth synonymous?"

"Yes, they are identical."

"Then history is neither science nor truth."

"No — that is ——"

"Can the material of history be applied to the guidance of affairs to-day?"

"Probably not, since events are not repeated."

"Since history cannot be applied, and since it is not truth, is there any reason why one should exercise any particular care in criticizing sources, citing sources, and representing sources?"

"I think nothing should be written that is not substantiated by the sources; the sources ought to be what they purport to be."

"Since the requirement is that you must engage in research and produce a thesis which is an original contribution to science or truth, and since you admit that history cannot be called science or truth, how do you expect to meet the requirement if you continue in history?"

"I -- I had not thought of this — I am not certain ——"

Problem 14: Show that history is or is not science, and therefore suitable or unsuitable for theses.

Special questions:

1. Does all science carry with it the power to predict, or is it merely a *desideratum* of science?
2. Are validity and reliability the only criteria of science?
3. Does the mere fact that one can substantiate the claim that what has been written has been taken from true sources give proof of the truth?
4. Can one establish that history is a powerful influence on human actions?
5. Would doing this be sufficient to prove that history can be applied to human affairs?
6. Would this contention, alone, indicate that history is applied science, not pure science?
7. Finally, is it not true that proof of application is itself proof of truth?

Bibliographical note: Consult references that explain the meaning of science. Next, consult such references as Avey, Albert E.; Black, J. B.; Croce, Benedetto; Fling, Fred M.; Fortescue, John; Freeman, Edward A.; George, H. B.; and Gooch G. P., in the following Selected References, for statements concerning the question whether history is science or not.

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CHAPTER VIII

MINOR METHODS AND DEVICES

Minor methods. Although this book has been written largely for the purpose of aiding graduate students at work on their own theses, the writer realizes that many of these same students will one day be directing research, or advising students engaged in research. They will need, therefore, to become critical of methods and devices in use and recommended. The writer has expressed the point of view that the preparation of a thesis requires research, and that research must be carried on by the scientific method. The types of these which satisfy the requirements of science have also been classified as three in number, namely: (1) normative, (2) experimental, and (3) historical.

At once the inquiry arises, "What about other methods now used?" References have been observed in the literature of thesis writing, to *case studies*, *surveys*, and *questionnaires*. The student probably is aware of theses that have been prepared by one or another of these methods and accepted as fulfilling the thesis requirement. Certainly theses have been prepared by other methods, and have found acceptance. Usually such theses have been written to fulfill part of the requirements for the M.A. degree; less often to fulfill the requirement for the doctorate. They have been written and accepted because:

(1) No uniform view has been held as to the nature and function of the thesis;

(2) The meaning of research has not always been clear; and

(3) Some teachers are indifferent to research.

The writer does not take the position that theses worked out by other than the scientific method should not be approved. Considerations may enter into a situation which would make such approval wise. The line between the scientific and non-scientific is occasionally quite vague, and can be seen only by careful scrutiny, but one should, in justice to himself and to his future, and in tribute to the work of the great scientists who have endeavored to substitute system, order, and law for the lack of system, chaos of opinion, and superstitious ignorance of an earlier period, *try* to realize the ideal. The scientific process is not difficult to master; Bacon had visions of the time when it would be carried on by morons — a conclusion which the present generation with its better knowledge of intelligence refuses to accept, but which, nevertheless, indicates that it is not too difficult to be mastered by any one who is entitled to the honor of an advanced degree.

Careful, accurate, and systematic work alone does not constitute the scientific method. It has a definite beginning in problem and hypothesis, and it proceeds from observed facts to principles by induction. In this chapter, a review will be attempted of certain processes or minor methods to which the term scientific has been applied, with a discussion of their meanings and limitations. Those minor methods, as they have been called, are seven in number, namely: (1) the case study; (2) the case history; (3) the genetic; (4) the comparative; (5) the survey; (6) the reading and organizing method; and (7) the questionnaire.

1. *The case-study method.* The case study is a summary of an infinite number of traits and characteristics of a single individual; a cross section of an individual selected on the basis of some conspicuous quality. The "case" may be a delinquent, a dependent, a genius, an artist, an event, a plant form. When the description deals with mental traits only, it is called a psychograph. The design of the case study is to give so complete a picture of the subject that a diagnosis may be made, and characteristics associated with, or the cause (or effect) of the quality on which the selection was made, be identified. Case studies are made in law, medicine, psychology, sociology, engineering, and to a more limited degree in the natural sciences.

A sound criticism of the case study method is made by Lundberg.[1] He says: "The case method is not in itself a scientific method at all, but merely the first step in scientific method; individual cases become of scientific significance only when classified and summarized in such form as to reveal uniformities, types, and patterns of behavior." Only when data on numerous cases are combined and norms are reached does the case method become research. No acceptable generalization can result from one or a small number of cases.

The case study has certain practical values. It is a record of an experience. If the experience was successful, it may be repeated. Physicians make elaborate case records; from these they pass to diagnosis, and from diagnosis to treatment. In doing so they are really going from a general principle to a particular case; that is, their diagnosis leads

[1] George A. Lundberg. "Case Work and the Statistical Method," p. 61.

to application. The process is deductive, not inductive. Only one step, the collection of observations, has any relation to the inductive process.

2. *The case history.* A case history traces the origin and the development of the individual, selected because of some special characteristic. It is, in a sense, a type of biography. It may be continuous, covering a day-to-day, year-to-year development, or it may represent cross sections taken at different periods. Usually the case study represents direct observation at intervals, the gaps being filled in by appeal to memory or documents. When objective data may be obtained they are used; when they are not to be obtained, the case history utilizes simple description. The case history is generally a combination of the objective and the subjective, without discrimination.

The interview is a special type of case study, with or without the historical aspect. The dates, ages, and other numerical statements contained in the interview can usually be verified; but the typical statements of opinion, likes and dislikes, etc., have little or no reliability. Although the technique of the interview has been quite well standardized, it nevertheless does not furnish a scientific method. Its deficiencies are the deficiencies of case studies in general Interviews and case histories may lead to norms, but if the norms are to be dependable only verified data should be utilized.

3. *The genetic method.* The genetic method is similar to the case history. It differs slightly in purpose, since its objective is to understand the whole course of development — how it was brought about as well as what happened.

Woodworth describes the genetic method in psychology as follows: [2]

> The object is . . . to trace the mental development of the individual, or of the race. It may be to trace the child's progress in learning to speak, or to follow the development of language in the human species, from the most primitive tongues up to those of the great civilized peoples of to-day. It may be to trace the improvement of a performance with continued practice.

The relationship between the genetic method and experimental and historical science is also revealed in the quotation. An investigator who traces "the improvement of a performance with continued practice" must conduct an experiment, if his results are to have any meaning; an investigator who follows "the development of a language" must use the historical method.

The genetic method is well illustrated in Loomis's *The Evolution of the Horse*. The study covers a wide scope, both in time and space. Tabular data are lacking; the treatment is in broad descriptions, usually abstract and generalized. Where specific data are reported the methods of physics and chemistry have been applied, not to reach generalizations, but to go to the particular. One can say, therefore, that where an effort has been made to be inductive the data are so incomplete, the gaps are so numerous, and verification is so difficult that the work stands as less scientific than history; the generalizations are probably true, but not certainly true.

The genetic method passes over into the normative in Terman's *Genetic Studies of Genius*. A large number of cases were studied by the case-history and the measurement techniques. Norms of the group were calculated. The

[2] R. S. Woodworth. *Psychology: A Study of Mental Life*, pp. 15–16.

norms were compared with norms of unselected groups. Other data have been gathered subsequent to the first studies, and the proposal is to continue to an indefinite period. Such an investigation has its scientific value almost wholly in the norms which may be derived. As was stated in considering case-study methods, the genetic method is only the beginning of science. When it becomes really scientific it is identical with the normative, experimental, or historical sciences.

Emphasis in the genetic method is upon the dynamic factors of growth, change, and progress. It attempts to describe existing facts through studying the course of their previous development. If the data of the genetic method are specific facts they must have a specific source: documents, practice, or controlled experiment. Where, though, are the sources of the genetic method? They are in none of the sources named. When examined critically in evolutionary studies, where the method is seen at its best, the sources appear to be unestablished hypotheses which have been generalized in a systematic order. Some of the hypotheses have passed towards the stage of principles, but their bases are typically unsound and weak. There is not a coherent, logical progression along an inductive road.

4. *The comparative method.* The comparative method is at times allied with the genetic; at times they are considered as identical. According to Woodworth,[3] in the comparative method:

You see what behavior is typical and what exceptional. You establish *norms* or *averages*, and notice how closely people cluster

[3] *Op. cit.*, p. 14.

about the *norm* and how far individuals differ from it. . . . Further, by the use of what may be called double comparison or "correlation," you work out the relationship of various mental traits.

Obviously there is no distinction here between the comparative and the normative methods. In one sense, a difference is found in practice. When the difference is found, it arises out of the comparison of individual units, not of central tendencies. The costs of parks are calculated in fifteen cities, and the cost in the subject city is matched against the cost in all the other cities studied; not against the average of the group. To make the comparison, the cities are arranged in order, the highest costs at the top of the table. The table given below will serve to illustrate the point:

TABLE II. SALARIES OF PRINCIPALS AND TEACHERS OF JUNIOR COLLEGES IN CALIFORNIA — ILLUSTRATING SIMPLE COMPARISON

Name of Junior College	Salary of Principal	Rank	Salary of Teachers	Rank
Chaffey (Ontario)	$8500	1	$2777	6
Pasadena	8000	2	2760	9
Marin Union	6000	3	2764	8
Fullerton	5700	4	2727	10
Glendale	5508	5	2775	7
Sacramento	5400	6	2794	5
Long Beach	5150	7	2614	11
San Bernardino	5004	8	2891	1
Santa Ana	4500	9	2800	4
Riverside	4500	9	2775	7
Modesto	4250	10	2803	3
San Mateo	3600	11	2854	2
Santa Rosa	3250	12	2172	12

5. *The survey method.* The survey method is an extension of the case-study method, with the addition of comparison wherever possible. The survey is usually applied to institu-

tions and to political units, such as schools, orphanages, churches, cities, and counties. It is also applied to social conditions in definite areas, such as neighborhoods, communities, districts, and wards; and as surveys of poverty, crime, vocations, wealth, or modes of recreation.

A survey is made by analyzing the field into sections or divisions, and by collecting facts on each from the area being studied. The facts are then reported, with similar data from comparable areas, and the subject is located in respect to the comparable areas chosen. Where norms are available, they are used in the place of the individual comparisons. In so far as new norms are developed a survey makes a contribution; in so far as it utilizes norms already prepared the process is simply one of deductive application. In so far as simple comparisons are made the process is not scientific at all. Thus the survey method, when it becomes scientific, is normative science; unless it is normative it has no higher status in the realm of science than the case-study or the comparative method.

The general survey should, therefore, be ruled out as a thesis method. If carried out by the usual techniques, and covering the usual topics, the scope is too broad to admit of the kind of intensive treatment which should be the aim. It contains no hypothesis; it reaches conclusions, not principles. It has application, rather than truth for its aim. If the field is sufficiently narrowed so as to be practicable, the method of research which can be employed on the type of problem of the survey sort is the normative. No value attaches to calling the normative method the survey method, and *vice versa*. The survey should be regarded as typically

non-research activity of practical value, but which makes no contribution to truth. Its usefulness, so far as theses for degrees is concerned, lies with the master's degree, rather than with the doctorate.

6. *Thesis making by compilation.* The writer has before him a booklet containing directions for preparing what is called the "reading thesis." The statement is made that a reading thesis involves: (1) an original organization; (2) around a definite proposition; (3) about which all available material in print is collected; (4) including all original sources; and (5) a critical evaluation of all secondary discussions, (6) for some constructive purpose. "The difficulties," the report states, "lie in attaining originality, completefulness, and purposefulness, in a field where the same problem may have been the subject not only of original research but even of purposeful evaluation and interpretation by others."

Although original sources are mentioned (4), evidently what is contemplated is not a thesis based on original sources only. Although there is no question about whether a useful piece of work is possible by this method, such a thesis cannot satisfy the requirements where research is specified. The organization and interpretation of all the facts and principles of the respective fields — these are tasks to which many scholars must devote themselves. An interpretation and organization of the research of others is hardly the task for one until he has become a mature scholar, with a superior background in learning and experience. It is the ultimate, rather than the beginning. Apart from this issue, however, such a thesis conflicts with the intent and significance of research. Independence is aimed at in graduate study; and

the thesis should stand as the highest example of the individual's capacity to do independent work.

7. *The questionnaire device.* The execution of research projects requires devices. Apparatus in experiments, correlation charts in normative science, the outline followed in writing — all are examples of devices, defined as that which is devised or formed by design — a contrivance, an invention, a project. Synonyms are invention, design, tool, instrument, adjunct. Among all of these devices, there is one whose use in thesis making is a matter of debate. This is the questionnaire.

The difference between method, technique, and device might well be noted. Method has reference to basic process, including the underlying principles. It is the groundwork which determines and constitutes the plan. Technique is the art of executing the plan: the style of performance in any art, skill, execution. The Germans call *die Technik*, the most satisfactory combination attainable of practical aims and scientific means. This restricts the meaning, so far as science is concerned, to the applied side. Technique commences to operate after principles have been discovered. Device is an instrument, a tool; it is a means to an end, while technique is skill in its use.

To return to the questionnaire, we may say that it is a device used in collecting materials. Particularly is it advised for the collecting of what have been called "unrecorded specifics," items of information, opinion, and belief carried around by every one. Three points of view may be detected concerning it; there are: (1) those who hold it has no value for research, (2) those who hold that it has value

for research, and (3) those who hold it has practical value but no research value.

Value of the questionnaire. Although our chief concern is in the question: "Is the questionnaire of value in research?" the question of whether it is of any value at all cannot altogether be ignored. The questionnaire process is almost identical with the interview, the difference being that in the interview the inquiries are put personally and directly, while questionnaire information is supplied without the presence of the questioner. One is the oral interview, the other the written interview, or correspondence method.

Koos,[4] who has published the most extensive study of the questionnaire, had 143 questionnaire studies evaluated by competent judges. Out of this total only 11 were rated as having "exceptional value," 87 were rated valuable but not exceptional, 43 were rated as having some but only moderate value, while 2 were rated as having no value at all. Value is expressed not as scientific research, but in application to practical affairs.

Hobson finds it less valuable than the interview. He says:[5]

> As compared with the personal-interview method of gathering data from original sources, correspondence is open to much criticism. On the whole it can be said that the correspondence method is unsatisfactory because of the unreliability of the data obtained in this manner. . . . But with all its faults, its use is indispensable to the investigator in gathering certain classes of data. First-hand

[4] L. V. Koos. *The Questionnaire in Education,* pp. 57–58.

[5] Asher Hobson. "Use of the Correspondence Method in Original Research," p. 210.

information which pertains to a wide area, or data concerning segregated districts separated by great distances can be obtained, without the expenditure of large sums, only by correspondence.

Douglass likewise claims practical value for the device, and connects its use with research. According to his view: [6]

> There are many people — particularly those teaching and studying in fields, where by the nature of the field, questionnaire methods cannot be used in research, and those who by practice imply a disbelief in the value of any research — who direct all manner of puns and jibes at the questionnaire method. The first of these are not conscious of the difference in the possibilities of various methods of research in different fields. Research in mathematics, history, or chemistry, for example, can hardly be carried on by the questionnaire method. Neither can research in school administration be carried on by manipulation of equations in a chemical laboratory; or in newspapers, diaries, or talks with old residents.

Use of questionnaire by leaders. Of the leading scientists of the world, few can be found who have used the questionnaire. In foreign countries, Galton is an exception. He used the questionnaire in his study of *English Men of Science*, and in his study of twins. Although some of his generalizations have been verified, his work was not free from error. Two of his chief faults were to generalize on insufficient data, and to fail to take account of all factors. Though he deserves credit for deep insight and true scientific spirit, it must be confessed that his reputation has not been enhanced by his questionnaire studies.

In this country, the leader in questionnaire studies was G. Stanley Hall. His questionnaires, chiefly in child study, called for long answers. Often the replies were difficult to tabulate; some of the questions were leading, others were

[6] H. R. Douglass. "The Questionnaire — To Be or Not To Be?" p. 398.

answered either in the same way or left blank. The treatment consisted in giving representative replies, or in summing up the whole in qualitative terms. The total effect was to bring the device into early disrepute.[7]

Conclusions as to value. The practical value of the properly framed questionnaire is not to be doubted. To doubt it would be to doubt the reliability of correspondence, in general. Prices, statement of accounts, business propositions, offers of marriage, descriptions of historical events, the stock market, and a nearly endless list of other matters enter into correspondence, and absolute faith is put in them. People can safely depend upon *some* questionnaires for reliable data of practical import. There are questionnaires and questionnaires, and since no two situations in which they are used are exact duplicates of each other, the reliability and validity of each will have to be determined independently of any general conclusion that they are or are not dependable.

One who is acquainted with historical method is not likely to claim that the questionnaire can be used as a basis for scientific history. It might lead to the uncovering of unknown sources, or might aid in interpreting a document or fact, but it can never substitute for the document. Likewise, no one claims that the questionnaire is identical with or can take the place of the experiment. If it has a place at all, it must be in the normative sciences.

Before considering that place, let us take up one of the defenses of the questionnaire: namely, that there are certain problems which can be solved by no other method than the

[7] See E. L. Thorndike. *Educational Psychology*, vol. I, pp. 28–37.

questionnaire. Hobson mentions "data which pertain to wide areas or concerning segregated districts,"[8] and Douglass intimates, if he does not assert, that the questionnaire method is indispensable in school administration.[9] Do these statements, though, hold so far as research is concerned? Grant that the correspondence method is desirable in getting at the price of sugar, and the dividends paid by coöperative creameries; grant that it will inform a school administrator as to the salary schedule of janitors in a comparable city, and the policy concerning the employment of married women; still, does it give a single principle, universal, true? Certainly there are other methods than the questionnaire applicable to school administration. A history can be written from documents, experiments may be conducted, and norms may be established. No one contends that research in school administration can be carried on in a chemical laboratory, but no one disputes that statistics may be applied to such research.

The conclusion arrived at here is that the questionnaire is a useful device, and at times indispensable in practical affairs. As an instrument of research, its use is confined, with one exception, to early and preliminary stages. This exception is in normative science, where, if properly used, the questionnaire may function in obtaining expert judgment (as a criterion), and in gathering recorded data that cannot readily be obtained otherwise. In the last analysis, for a student on the western coast to have a college record in Boston copied for him is not essentially different from his having an historical document in London photostated

[8] *Op. cit.*, p. 210. [9] *Op. cit*, p. 398.

Conditions of usefulness. The usefulness of the questionnaire is conditioned by its meeting standard research requirements: validity and reliability. There is no use in denying that much questionnaire data is not dependable. Koos states that, in the studies he examined, there was no large extent of validation.[10] At the same time, he says, "a variety of procedures are at hand for validating the returns from questionnaire investigations." [11]

Reliability of questionnaire studies is also often doubtful. One of the most startling pieces of evidence of unreliability has been found in contrasting the questionnaire studies of the teacher's health with later statistical studies. The questionnaire studies reported a high incidence of disease and disorders, with nervous troubles standing near the top of the list. The findings were alarming enough to cause one to wonder how any teacher survived to enjoy her pension. Since 1921, however, statistical investigations to the number of five or six, two of which were very extensive, have refuted every conclusion of the questionnaire studies.

There is also the fact that a questionnaire study is difficult to administer, and that, with the passage of time, it becomes progressively more so. Few people like to answer questionnaires of the type and of the extent demanded by thorough investigations. Fifty per cent of returns is normal; only when exceptional care is used in the form, when special inducements are offered for a reply, and when the subject is of exceptional interest and importance can an investigator realize a seventy-five per cent return. Dogged persistence in follow-up is associated with the method, too, as a matter of course.

[10] *Op. cit.*, p. 138. [11] *Ibid.*, p 143.

Advice then sums itself up in one simple statement: "Avoid a questionnaire study for a thesis, except as a last resort." Choose some more reliable, more convenient, and more reputable plan of work. Select a problem that can really be solved by the historical, experimental, or normative methods, using standard devices. If there is no other recourse, then first become thoroughly acquainted with the procedures laid down in standard textbooks in statistical method. Examine critically the work of others who have used the device. Select the sources of data wisely, and persevere in follow-up work until adequate sampling has been obtained. Treat results adequately, and finally submit them to verification.

Summary. Certain procedures of investigation are sometimes given the status of independent methods. Among these are the case study, the genetic, the comparative, the survey, the summary, and the device known as the questionnaire. A critical examination of the minor methods enumerated shows either that they are inadequate as methods of inductive science, or that they are identical with one of the standard methods: historical, experimental, and normative — particularly the last. As independent methods they do not result in generalizations; they tend rather to go from the general to the particular. The questionnaire has a useful function in applied studies, but it is very limited in value as a vehicle of research. The probabilities are so great that the results will prove inadequate and unreliable that it should be avoided in thesis making, except as a last resort.

QUESTIONS AND EXERCISES

1. Inspect a few theses in various fields, chosen at random, and note what proportion make use of one of the minor methods named in the discussion.
2. If the procedures which have been described in this chapter are not scientific, how do you explain the fact that theses have been accepted which used them?
3. What is lacking from the point of view of scientific method in the case-study plan of work?
4. Is a case history giving a longitudinal view of a subject of any more scientific value than a cross-section or case study?
5. Do these procedures result in information of practical value? Do they on this account make suitable procedures for thesis making?
6. Examine a questionnaire used by Galton or by G. Stanley Hall, and criticize it in the light of what is practiced in the preparation of questionnaires to-day.
7. Contrast the comparative method and the normative method.
8. Have great scientists usually used the questionnaire in their investigations?
9. How does a survey differ from research beginning with an hypothesis, collecting data, and ending in a generalization?
10. Can scientific method be used in surveys? Discuss.
11. Is there any possibility of finding new truth in preparing a thesis by compiling materials from others?
12. Read the article by Burk, "On a Certain Questionnaire," and the reply by Douglass, "The Questionnaire — To Be or Not To Be?" What is the issue? Is it satisfactorily settled? Write a brief article on the subject in which you make what you think is the proper adjustment.

PROBLEM 15

A Study of Leadership

Situation 15: Mr. Brooks, a graduate student in the University of Carizona, is particularly interested in leadership. He does not

believe it is a simple characteristic, but looks upon it as a complex of many factors, of varying weights. He has no hypothesis concerning its nature further than has been indicated. He wants to study it, using the results of his study as a thesis.

His proposal is as follows: (1) to make case histories of a number of recognized leaders, (2) to make case histories of high-school students rated by their teachers as being superior in leadership, and (3) to make case histories of students in high school rated by their teachers as having little leadership ability. He expects also to study an unselected group of high-school students as a control.

He expects to have quantitative data on the high-school students on such matters as age, grade, scholarship, intelligence, height, and weight. He expects to write a description of all the material he has, qualitative and quantitative, treating the groups separately. He thinks he can reach some broad generalizations concerning leadership from his facts.

Problem 15–A: Will this problem and this treatment give an acceptable thesis?

Problem 15–B: If the conclusion is not in favor of Mr. Brooks, how can a problem be framed on this general subject, and how can it be treated?

Special questions:

1. Is an hypothesis necessary before an investigation can be made?
2. Can a contribution to knowledge be made by the case-history method?
3. What criticisms can be brought against the data and the method?
4. How does the method differ from the normative method?

Bibliographical note: Considerable attention should be given to the case-history method. Read Bogardus, *Making Social Studies;* Crawford, *The Technique of Research;* and Park and Burgess, *Introduction to the Science of Sociology.* After reading some of the texts that have been mentioned, look over a few typical reports in which case studies have been used. Healey has an interesting

book called *The Individual Delinquent,* in which the content consists largely of case studies.

PROBLEM 16

The Genetic Method

Situation 16: A difference of opinion exists in Professor Adams's class in Principles of Research over the genetic method. Mr. Carroll declares that the method is scientific. He illustrated the method, first, as follows:

"Several case studies have been made of babies. In a typical investigation, a number of items of information were collected shortly after the child was born: its height, weight, reflexes, instinctive responses. Thereafter, further observations were made once or twice a day for three years. Intelligence was tested, measurements of height, weight, strength of grip, etc., were repeated. Radiographs were made showing the development of the bones and the teeth. A complete list of all the words in the child's vocabulary was kept, with the date of their appearance. The whole, when written up, constituted what might be called *The Biography of a Baby.*"

Mr. French pursued the question in another direction. "Suppose," he said, "that in place of the baby we substitute some lower organism; I suggest, for illustration, a sand flea. We follow the same precise method suggested by Mr. Carroll. We weigh the insect shortly after it is hatched; we measure it at frequent intervals. We find all we can about its life habits. The question in my mind is whether we can state any generalizations from our genetic study that will hold."

Mr. Webber was of the opinion that no generalization would prove acceptable from the study of an individual, even though the study extended throughout his whole period of development. The chances of error were too great; individual differences are too pronounced. More than one case or individual would have to be included, and averages of the measures taken at identical periods computed. From these averages, or at least from a consideration of all the facts about many individuals, principles might be reached that would bear the stamp of truth.

Other members of the class pointed out, at this junction, that if Mr. Webber's plan was followed the study would be of the normative type, while the real question is whether developmental studies of a single individual or of a small group could give data from which generalizations universally true, or empirically true, would hold.

Problem 16: Can science be derived by the genetic method, without the derivation of norms or central tendencies?

Special questions:

1. Could not one assume safely the uniformity of nature: that basically what is true of one child or one sand flea is true of all?
2. In what form should generalizations be presented in a thesis?
3. Is it possible to formulate an hypothesis about an individual subject, or case, independent of comparisons with others?
4. Does not the very term "case" imply the typical?

Bibliographical note: See references from the bibliography, and consult, especially: Gee, Wilson, ed. *Research in the Social Sciences*, chaps. I, II, V, and IX.

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CHAPTER IX

THE LIBRARY AND THESIS WRITING

The library and the thesis. A thesis is something more than a collection and an interpretation of original data. From the point of view of content, it is a combination of the original data gathered by the student and of the research work done by others. The research work of others is referred to in the thesis in two forms: (1) in the written review of related literature, placed near the beginning, and (2) in the bibliography, the comprehensive list of all associated publications on the subject, which comes at the end of the thesis. The introductory review is comparable to the genealogical tree from which the special topic of investigation was descended; the bibliography comprises the material directly and indirectly related to the study. One is connected with the special topic, the other with the general field. Although, except in history, one does not normally obtain his data from the library, a thesis cannot be completed without library reference. "Existing knowledge is the basis of discovery."

The thesis, too, is a measure of the scholarship of the student, no less than of his research ability. A scholar must have many items of information at his command; he is also constantly in need of adding to his store of knowledge. While he may be expected to remember many things, his scholarship will also depend upon his ability to find what he needs quickly and accurately when he needs it. An ability to use the library is frequently looked upon as an essential

to college admission; no one is qualified for graduation, and much less for graduate study, until he is master of a reasonable efficiency in library technique.

The library and research. Only by reading what others have done can the student judge the originality of his own work. Thorndike recites an experience which reveals that not all students are aware of this patent fact. He received a letter describing a piece of research which the writer wished to offer as a thesis. "I know the problem is original," the writer said, "because I have carefully refrained from reading anything on the subject." Had he read, he might have discovered that what he believed to be original was really very old. He might have found his problem had already been solved, or that the method which he hoped would yield satisfactory results had already been proved to be of no value. Much fruitless labor may be saved by becoming acquainted, at the outset, with the research work which has been done and which deals with similar and related topics. Severance[1] says:

> Periodicals aid research by furnishing the research worker with two kinds of information: (1) The results of work in research which have been completed, so that the research worker may not spend effort on a problem which has already been solved; (2) The results of work in the same field as the problem chosen, or some phase of the problem, and the results of work in other fields which are related to his problem and may contribute to the solution.

The prevention of duplication is not the only reason for giving serious attention to the material in the selected field. The investigator needs the guidance of those who have preceded him. He needs to know their objectives, their sources

[1] H. O. Severance. "How Periodicals Aid Research," p. 590.

of material, their methods of attack, and their results. He need not follow them slavishly, but he is short-sighted if he does not learn from their experiences. The investigator is like the pioneer: for some distance he follows the trails blazed by others, but at last he pushes on into the unknown, and leaves his own records to guide others. Books are sources of ideas, and clues to discoveries. De Kruif emphasizes this point, in his essay on Paul Ehrlich:[2]

> He lived among his scientific books, and subscribed to every chemical journal in every language he could read, and in several he couldn't read. Books littered his laboratory so that when visitors came and Ehrlich said, "I beg you, be seated!" there was no place for them to sit at all. Journals stuck out of the pocket of his overcoat. . . . And what was important, inside of those books, was in the brain of Paul Ehrlich, ripening, changing itself into those outlandish ideas of his, waiting to be used. That was where Paul Ehrlich got his ideas — you would never accuse him of stealing the ideas of others! — and queer things happened to those ideas of others when they stewed in Ehrlich's brain.

The value of library work is also illustrated in the life of Faraday. When a young man, he observed an experiment by Dr. Wollaston and was greatly interested. He very properly realized that, before attempting anything similar himself, he must first make a careful study of what had been done. He began an extensive course of reading and experimentation, which culminated in his publication of *A History of the Progress of Electro-Magnetism.*

Only when combined with what has gone before does a thesis acquire significance. The powers of the individual are finite. Progress results when the work of one investigator is combined with the work of others. When one is asked,

[2] Paul de Kruif. *Microbe Hunters*, p. 342.

"What does this investigation mean?" he should be able to state what has preceded it, what he has added, where it is going, and how it is related to life. From the library, then, the student learns the degree of originality in his own research, the methods and achievements of investigators in the same field, the relation of his work to what has been done before, and he also glimpses something of the road yet to be traveled to the ultimate solution of the whole problem.

This is a matter to which many an ardent young scientist, impatient for discovery, fails to give sufficient attention. He follows no careful method of study which insures that he will master the field. His note-taking is haphazard, his references are not well arranged, his ignorance of library methods causes him loss of time, and his failure to appreciate the importance of previous investigations results in an incomplete survey of the literature of his problem. He cannot distinguish between what is important and what is unimportant in his own work because he has no perspective, and he impresses his thesis committee as an untrained and uncultured bungler. In the preparation of the bibliography, just as surely as in the research itself, an opportunity is given to display both ability and scholarship.

Criteria of a bibliography. As one proceeds in his collection of a bibliography, he should check it against three criteria: (1) completeness, (2) accuracy, and (3) effective organization.

1. *Completeness.* Few bibliographies attain absolute completeness, but any good list of titles approaches that ideal very nearly. Completeness is dependent upon four factors: the extent of the library to which the student has

access; the mastery of library technique which the student possesses; the time available for library work; and, perhaps most important of all, his ingenuity in discovering sources of references.

All of these factors are to some extent within the control of the student. For important work, the available materials can be increased by borrowing from other libraries, or by special purchase. By starting library work early and working diligently the time factor can be overcome. By keeping the problem constantly in mind and by a systematic method of search, the chances of finding new sources can be increased. Finally, a knowledge of library resources and technique can be acquired by a little study — study which will amply repay the effort involved.

2. *Accuracy.* Accuracy is the second essential of a good bibliography. After what has been said about the requirements of the scientific method, it is perhaps unnecessary to reëmphasize the importance of accuracy in every phase of a research enterprise. The student should not forget that others will use his bibliography in the future, that these persons probably will not have access to exactly the same sources of information as he has, that they will depend upon his bibliography, and that perhaps they will judge the whole of his work by the reliability of his references. Few things are more annoying than to search long and carefully for a reference, only to find at last that it has been incorrectly given. A regard for the convenience of others, therefore, as well as for the safety of his own reputation as a scholar, will cause the student to be exact in his citations.

3. *Effective organization.* The best organization for a

bibliography is generally the one that will make it most convenient to use. No absolute rule on this point, therefore, can be given, but the matter will have to be settled in accordance with the peculiar conditions of each individual piece of research. A few of the more common methods of classifying and arranging references may be made now, leaving to later pages the consideration of procedure in finding materials. Bibliographies may be organized:

1. As original material, and as secondary material. This is often done in historical studies.
2. Alphabetically, by the last names of the authors. The merit of this plan is its simplicity; its weakness lies in the fact that it gives no clue to the contents of the bibliography.
3. Chronologically, by date of publication. This scheme is useful in historical studies, but has serious limitations elsewhere.
4. Geographically, by place of publication, place referred to, or language used. This method is very useful in comparative studies.
5. Topically, by chapters or divisions of the thesis. This method is not widely used, but it has many advantages. In using it, one has to make cross-references from topic to topic in order to include general works.
6. By type of material: as, books, documents, periodicals, unpublished works.
7. By any combination of these methods, the most popular being 1 and 2, and 3 and 5.
8. Newspaper items are listed by title, but, unless few in number, these are given a separate place in the bibliography.

Library classification. The efficient use of the library is dependent to no small degree upon an understanding of library classification and notation. Although many systems of classification have been created (over 160) and many are

in use, most libraries are arranged on one of three plans: (1) the Expansive, (2) the Dewey Decimal, and (3) the Library of Congress plan. The second leads in practice, but the scheme adopted by the Library of Congress is being adopted by more and more libraries, not only because it has certain advantages in flexibility and in accuracy in use, but because the Library of Congress is able to supply printed catalogue cards ready to put into the files.

The Expansive and the Library of Congress schemes use the letters of the alphabet to designate their main divisions, and Arabic numerals for subdivisions. The Dewey Decimal system uses Arabic numerals to designate its main divisions, the decimal point separating the more general divisions from the particular. The resemblances and differences in the general classes can best be seen by comparison:

Expansive		*Dewey Decimal*	
A	General Works	000	General Works
B	Philosophy	100	Philosophy
Br	Religion	200	Religion
D	Historical Sciences	300	Sociology
H	Social Sciences	400	Philology
L	Sciences and Arts	500	Science
R	Useful Arts, Technology	600	Useful Arts
V	Athletic and Recreative Arts	700	Fine Arts
Vv	Fine Arts. Music	800	Literature
X	Arts of Communication by Language	900	History

Library of Congress

A	General Works
B	Philosophy, Religion
C	History, Auxiliary Sciences
D	History and Topography (except America)
E–F	America

G Geography, Anthropology
H Social Sciences, General
M Music
N Fine Arts, General
P Language and Literature
PN–PV Literary History, Literature
Q Science, General
R Medicine, General
S Agriculture, Plant and Animal Industry
T Technology, General
U Military Science, General
V Naval Science, General
Z Bibliography and Library Science

The character of the Dewey system may be seen further by considering a single class, Science. Its number is 500. The first subdivision, 500–509, stands for Science in General, 510–519 for Mathematics, 520–529 for Astronomy, 530–539 for Physics, 540–549 for Chemistry, 550–559 for Geology, 560–569 for Paleontology, 570–579 for Biology, 580–589 for Botany, and 590–599 for Zoölogy. The subdivision Physics is indicated by the term, 530–539, in which 530 stands for Physics in General, 531 for Mechanics, 532 for Liquids, 533 for Gases, 534 for Sound, and so on. Under 534, Sound, 534.1 signifies Theory, 534.2 Propagation, 534.35 Musical Sound, 534.4 Analysis, 534.5 Superposition of Vibrations, and so on. The division may be carried on indefinitely simply by adding more numbers to the decimal. Thus the next division of Theory of Sound would be 534.11, the next 534.111.

The author's number consists of the initial or the first two letters of the surname, combined with one or more numbers. The class number plus the author's number make up the call number of the book. The call number for Northup, Clark S., *A Register of Bibliographies of the English Language and Literature*, is

016.01
N878

in which 016.01 is the class number, and N878 is the author's number. It is necessary to know the call number in order to find a book readily on the shelves.

The system used by the Library of Congress carries analysis much further, and the completed tables fill hundreds of pages. The division of Political Science alone requires 340 pages, of which 264 pages are given to the tables. Over ten thousand places are provided in the schedules of this one field. The letter J stands for official documents, JA for General Works, JC for Political Theory, JF for Constitutional History and Administration, JK for the United States, and so on down to JX which stands for International Law. Under the letter headings numerals appear. HD, Economic History, has such subdivisions as 21 General Works, 82–91 Economic Policy, 101 Periodicals, and 105 Congresses. In addition, each sub-class is analyzed into many subsidiary tables, each item with its appropriate symbol. From the point of view of analysis the system leaves little to be desired, and doubtless it is due to supersede other systems in new libraries and in those of national proportions.

Library materials. Library materials may be classified conveniently under four headings: (1) books, (2) serials, (3) documents, and (4) bibliographies. The use of each of these will be considered briefly, in order.

1. *Books.* Books may again be divided into references, and texts. Examples of reference books are encyclopedias, atlases, and dictionaries. Books supply an outline of the topic, usually offer a selected list of special works to supplement their own treatment, and lead in sources. Unfor-

tunately reference books soon get out of date, and, as it is expensive to make thorough revisions, one cannot count on more than a partial and a somewhat out-of-date treatment on many topics in using them. They may well be consulted, however, as a first step in preparing a bibliography. Reference books are generally available in the general reading room of a library, and, if one is new to the institution, direction should be sought from the reference librarian.

The card catalogue is the port of entry to the books of any library, and this source of information should be explored thoroughly under the special subject heading, and under related topics. The student should also go directly to the shelves and look over the books, as by this means he not only obtains a better idea as to their contents and usefulness, but he also will probably find material to which the best card catalogue would not guide him. Related books also should be examined. If one were making up a bibliography on *Ferns*, he would first go to the class 580, but he would also find it advisable to look under 500, which is Science-General; 550, which is Geology; and 570, which is Biology.

Each book is usually represented in the card catalogue by three cards: an author card, a subject card, and a title card. Knowing the author, the easiest method of entry is to find his card. Knowing the title, but not the author, one should find the title card. In most instances, in making a comprehensive bibliography, only the subject will be known. To illustrate, suppose one were making up a book list on the subject, *Ferns*, he would find, in order, such references as:

Ferns
Maxon, William Ralph
The Tree Ferns of North America

If the book contains selections by several writers, one will find an analysis of the contents on the card.

Van Hoesen and Walter declare that every bibliographical pedagogue will emphasize the fact that you should always *see* the book you put on your list. They say:

> You will have to do this anyway for purposes of analysis and criticism, but even in matters of physical description, biographical sources are likely to be incomplete and unreliable in details, and should always be checked up. You are reasonably, though never entirely safe in copying a title from the library catalogue for insertion in your file, since all library cataloguing goes through the hands of a reviser. You may find it worth while to buy printed cards such as may be obtained from the Library of Congress.[3]

Inasmuch as the reference form on the Library of Congress cards is standard for bibliography, the student should become familiar with it. Taking an author card for illustration, pp. 234, 235, first comes the call number, which in symbols indicates location, class, work, and author. There follows in order the name of the author (with life-span in years), the title, the imprint (publisher, place, date), the collation (number of volumes, number of pages, number and character of illustrations, and size), series or analytical note (e.g. Carnegie Institution Publications), notes or physical description of contents, literary or critical, and "tracing" or record of subject cards so in case the book is withdrawn all the cards can be withdrawn.

2. *Serials.* Serials comprise the second main division of library materials. Under this heading are included periodicals, publications of learned societies, and publications of

[3] Henry B. Van Hoesen and Frank K. Walter. *Bibliography, Practical, Enumerative, Historical*, p. 18.

Culbreth, David Marvel Reynolds, 1856–

378.74 V817ec The University of Virginia; memories of her student-life and professors, by David M. R. Culbreth, M. D. ... New York and Washington, The Neale publishing company, 1908.

501 p incl. front. plates, ports. 22½cm.

1. Virginia. University—Hist. 2. Virginia University—Biog. 3. Jefferson, Thomas, pres U. S, 1743–1826

8–31641

Library of Congress LD5677.5.C8
(Copyright 1908 A 219782)

Hooke, Robert, 1635–1703.

530.4 H782 Philosophical experiments and observations of the late eminent Dr. Robert Hooke, S. R. S. and geom. prof. Gresh., and other eminent virtuoso's in his time. With copper plates. Publish'd by W. Derham, F. R. S. London, W. and J. Innys, 1726.

4 p. l., 391, [7] p. illus, 4 pl. (2 fold) 20cm.

1. Physics. 2. Science—Early works. 1. Derham, William, 1657–1735, ed.

A 10–1720

Title from Leland Stanford Jr. Univ. Printed by L. C.

Library of Congress Cards, Reduced in Size

universities and colleges, and similar materials. Serials contain much valuable information which never finds its way into books. No other way offers of bringing one's information up to date. A book is somewhat out of date by the time it is published, for much that is new may have appeared after the references and contents were set into type.

Difficulties sometimes arise in finding serial matter. Ai-

McLaughlin, Andrew Cunningham, 1861–

973 ... Source problems in United States history, by
M161s Andrew C. McLaughlin, William E. Dodd, Marcus W. Jernegan, Arthur P. Scott ... New York and London, Harper & brothers, publishers [c1918]

xii p, 2 l., 3–513, [1] p. 19½cm. (Harper's parallel source problems)

1. U. S—Hist—Sources. I Dodd, William Edward, 1869– joint author II Jernegan, Marcus Wilson, joint author III Scott, Arthur Pearson, joint author. IV. Title.

18–18124

Library of Congress E173.M153
—— —— Copy 2
Copyright A 503438

LIBRARY OF CONGRESS CARD, REDUCED IN SIZE

though almost all magazines publish a yearly index, to go through each of these is a tedious task. Fortunately, the most important periodicals are indexed in the *Readers' Guide to Periodical Literature*, and in the *International Index to Periodicals*. When special subjects are under investigation, reference may be to the *Book Review Digest*, the *Dramatic Index*, the *Engineering Index Annual*, the *Industrial Arts Index*, and the *Agricultural Index*. When a periodical is not indexed in one of the guides, there is no recourse but the volume index. Fortunately, it is easy to discover whether a periodical is contained in the guide by consulting the list in the front of the publication.

Information is usually entered by subject, author, and title, following which is the abbreviated title of the periodical, the volume, inclusive page reference, and exact date. This form is not accepted as standard for thesis bibliography, and should be expanded by writing the title of the publication in full. Related subjects should also be sought

for in the headings, and cross-references followed up. A systematic order of using the guides is necessary, either beginning at the first and working forward, or at the most recent volume and working back.

Publications of scientific and professional associations form another important group of serials. They contain the names of members, refer to research in progress, report the results of investigations, give bibliographies, suggest problems, record the proceedings, and include committee reports. Minutes, resolutions, by-laws, and reports have considerable historical value, and may have other uses since they represent authoritative and expert opinion. Augmented by serial publications of universities and endowed research agencies, this division becomes most significant in bibliography making.

3. *Documents.* Under documents may be comprised the publications of national, state, and local governmental agencies. The varied publications of the United States Government constitute a great array of useful documents on subjects of interest, but unfortunately access is difficult because this material is inadequately indexed. A detailed survey of documents would be out of place here. For further information on this subject, one should consult Isadore Gilbert Mudge, *New Guide to Reference Books*, and the *Catalogue of Public Documents of Congress* and of *All Departments of the Government of the United States.* Documents of the States and municipalities cannot be summarized. They should be looked up in the card catalogue under the name of the geographical or political unit, or by subject.

4. *Bibliographies.* Time may be saved by consulting

bibliographies already prepared. The first reference should be to bibliographies of bibliographies, the subject, *Bibliography*, being sufficient to entry through the card catalogue These will be of two types, general and special. A bibliography may be comprehensive (complete as one can make it), or partial. A list of the "best books" on a subject is a selected bibliography. A bibliography for a thesis is special: for the student's use, it should be comprehensive; for the thesis, it may be selected.

Procedure in bibliography. Having completed a brief survey of the resources of the library, the next question is, "What is the best way to consult and utilize these resources?" While no rules can fit all cases, and while any method will need intelligent modification to meet the requirements of special circumstances, the following, nevertheless, is a satisfactory outline of procedure to follow to secure a reasonably complete bibliography.

1. Consult the general reference works. Read hastily through the articles bearing on the special topic to secure general orientation in the field. Make bibliography cards for the citations found at the end of each article. Do not make cards for general reference works, such as encyclopedias and dictionaries, unless they are quoted directly.

2. Consult the *Readers' Guide* and the *International Index* under all headings where information is likely to be entered. Make cards for all references found, and file these alphabetically, by author's name, to avoid duplicating cards.

3. Consult the *Yearly Index* to the *Record of Current Publications*, and the monthly numbers for the current year. Before making reference cards from these publications and

the ones to be mentioned later, check with the cards already made. There will be some overlapping in the various lists, and one may as well avoid unnecessary writing.

4. Go through the card catalogue. If any of the references so far are themselves bibliographies, secure these next, and make out cards for all new references found in this way.

5. Divide the cards thus accumulated into books, documents, and articles. Check the books and documents with the library catalogue, and record the library numbers on the cards. If any important book is not owned by the library, ask that it be purchased or borrowed. Look up the books in the stacks. If any are charged out or being rebound, request that you be notified when they are next available.

6. Arrange the articles according to the names of the magazines in which they are found. Find out which of these are available by referring to the library catalogue, under the title of the publication. Magazines are bound at the end of the year, and a few of the references may not be obtainable because the magazines are out of the library. Ask to be notified when they are returned. Examine all unbound magazines to which you can gain access. Bound magazines may be left to the last, as they are seldom taken from the library.

7. Determine what periodicals which apply particularly to the subject under investigation are not indexed in the *Readers' Guide*, and the *International Index*. See the first few pages of these publications for this information. If any such periodicals are found, go through their yearly indexes, volume by volume, making reference cards as the work progresses.

8. Organize all material that has been accumulated under general headings. Do not subdivide too finely. Unless the bulk of the literature is extremely great, three to ten subdivisions are the most practical. Maintain a "miscellaneous" or "general" section to take care of books and articles which take up two or more pertinent topics, or which deal in a very general way with the entire field.

9. When the bibliography is quite complete, begin reading on the most important articles on the most important topics. Take whatever notes seem advisable. New references will be discovered from time to time, often through the reading, but do not be distracted by them from the main object — reading. Make a card for each, and set the cards in their proper places in the organization of references, to be taken up in due order.

10. As you read, *check your references for accuracy and completeness.* When all that is useful has been extracted from the reference, check the corresponding card so that, at any future time, you will know that the article or book has been examined and the reference tested for accuracy and completeness.

11. Watch for chances to save time and effort. Make a note of the point in the search where you leave it, so that the work may be resumed without repetition. See that all references are right the first time. Above all, follow a definite system. Haphazard searching is bound to result in an incomplete bibliography. Do not give up easily. There are over 25,000,000 books and many more million articles in existence. It is hardly possible to name a subject on which enough literature does not exist to make a respectable bibli-

ography. To say there is nothing on a subject generally does nothing but reveal one's ignorance of it.[4]

Form of reference. The simple 3 by 5 bibliography card is acceptable for recording the first reference. The style should always be uniform, and, if writing for publication, one should consult the style book of some reputable publishing house, or such standards as are contained in *A Manual of Style*, published by the University of Chicago Press. As has been said, the Library of Congress card is standard, both in respect to form and content. In the selected lists at the end of the chapters of this book may be seen a uniform method of reference. In citing a reference a satisfactory system is to give:

1. The name of the author, editor, or compiler, transcribing the name as it appears on the title page, the last name first. The abbreviation "ed." in parenthesis follows the name of an editor, "comp." the name of a compiler, and "tr." the name of a translator.
2. The full title, taken exactly as published. If the title refers to the entire contents of the publication (a book, pamphlet, or document), it should be underlined with a straight line; if it refers to a part only (a magazine article or a chapter in a book), it should be enclosed in quotation marks. Underline only the title of the volume as it would be called for at a library.

[4] Van Hoesen and Walter (p. 15) recommend the following order in searching for bibliographical material: (1) encyclopedic and reference works in the special field, (2) the best and latest bibliographical manual or bibliography of bibliographies, (3) periodical bibliographies and reviews published subsequent to the preceding, (4) national and trade bibliographies which are always in advance of review notices, (5) special bibliographies and indexes, especially those of government publications, general periodical indexes, lists of publications of societies, and dissertations, (6) universal bibliographies, oftenest of use for exhaustiveness in compilation, and for verification of uncertain references, (7) information about unpublished works.

3. Number of edition, if it is indicated; if not, the understanding is that the first edition is meant.
4. Number of volumes, if more than one, and number of volume to which reference is made.
5. The imprint: name of publisher written in full, name of place of publication, and date of publication. If the place of publication is not given, use the abbreviation "n.p."; if the date is not given, use the abbreviation "n.d." If the date of copyright is published, it may be cited as "c.d." and the "n.d." omitted.

Examples of typical references are given herewith:

1. Book

907
D744 Dow, Earle W. Subject
Note-taking.

Principles of a Note-System for Historical Studies.

The Century Company, New York and London, 1924. 124 pp., 1 appendix.

2. Serial

Willits, J. H. Subject
Research, importance of

"The Importance of Research in Economic and Social Problems"; in *Scientific Monthly*, vol. 24, pp. 126–129. (February, 1927.)

3 Chapter of a book

025.4
S274 Sayers, W. C. Berwick. Subject
Library classification

"The Library of Congress Classification"; in *Canons of Classification*, Chapter VI. Grafton and Company, London, W. C., 1915.

4. Bulletin or pamphlet

Subject
Teaching personnel.

Practices Affecting Teacher Personnel.
Research Bulletin of the National Education Association, vol. VI, no. 4. (September, 1928.)

5. Newspaper

Subject
Cost of living.

"Living Costs have Declined in Two Years"; in *San Francisco Chronicle,* Section J, vol. CXXXIII, no. 127, p. 18. (November 19, 1928.)

The system of punctuation of a book citation is as follows: a comma is placed between the surname and the given name or initials; a period between the name of the author and the title or a comma after the name of the author when it is followed by *editor* and a period after "editor"; a comma after the title when it is followed by "edition," or page or chapter citation, or a period in case neither is given; a period after the edition, and after number of volumes; commas between the name of the publisher, the place of publication, and the date; and a period at the end of the entry. The form "ed. 2" is preferred to the form "2d ed.," though both forms are commonly used.

The reference card. The reference card may also contain a few critical notes concerning the book, article, or document itself: its content, method, value. The value of a bibliography is enormously increased if quite complete critical notes are appended to each reference selected, in which case, as a minimum, one would present such data as:

1. The writer's aim or problem.
2. The method — experimental, normative, historical, conceptual.
3. Sources or subjects.
4. Extent of originality in subject and technique.
5. Chief results of the inquiry.
6. Character of presentation: abstract, complete.
7. Critical evaluation of the reference.

On the 3 × 5 cards only a critical evaluation may be entered, but, if a complete annotation is undertaken, a special form of card will prove useful. This should be four by six inches in size, preferably ruled, and divided with proper headings. Although some variation in form and content may be expected, to suit the subject, field, and investigator, the chief essentials of such a card are shown on page 244.

Note-taking. The card form given will contain most of the information needed for the critical review of the literature of the subject, which in the thesis should precede the original data. In many types of research, however, more extensive notes will be desired. A reasonable possibility of future use is good reason for making notes, extracts, synopses, quotations, and noting down ideas. Loose sheets should invariably be used for this purpose; a student who values his reputation as a scholar will never use a bound notebook. Theme size ($8\frac{1}{2}$ by 11) is good where much future interpolation is likely to be done; note size (half sheet or $5\frac{1}{2}$ by $8\frac{1}{2}$) is best, though the 4 by 6 cards recommended for annotated bibliography are perfectly satisfactory, and are convenient for filing with the reference cards. It is a good plan to adopt a desirable size and then take all notes on that

Call Number

Author . . . . Subject . . . .

Title . . . .

. . . . Edition . . . .

Publisher . . . . Place . . . . Date . . . . . .

Volume . . . . . . Part . . . . . . Pages . . . . . . Cited by . . . .

Cross-Indexed . . . . Available at . . . .

Aim, problem, hypothesis . . . .

Method . . . .

Sources, subjects . . . .

Originality . . . .

Chief results . . . .

Presentation (full, brief, etc.) . . . .

Critical evaluation (errors, contribution) . . . .

. . . .

size of sheet or card. The method of filing will determine somewhat the type and size to use. If the filing is to be by folders and file boxes or drawers, the $8\frac{1}{2} \times 11$ sheet is preferable; if a card case is to be used, the smaller sheet or card is preferable.

The most important rule in note-taking is, "A sheet should contain no more than one unit: i.e. material on one topic." The type of material should also be isolated; an exact quotation on one sheet, an abstract on another, an idea or ideas arising from the reading belongs on a separate sheet. A quotation should be exact, and the fact that it is a quotation should be indicated by quotation marks at the time the notes are transcribed, together with the exact source. Three dots,..., signify the omission of matter, irrelevant to the student's topic. The safest rule is never to copy the exact words of another unless the fact is indicated. To paraphrase, the most embarrassing task the advisor performs is to include the quotation marks.

Citations to authorities. The review, and the body of historical theses, necessitates some method of citing the references or sources. A convenient way to do this in the non-historical study is to number the references in the bibliography in order, and cite by naming the author, giving the number, and year of publication, as Almack, (5:1928, pp. 162–165). In the historical thesis, and in others if one chooses, the reference number and footnote are used. The citation should be of such nature that it can be found readily. If the reference is complete in the chapter or thesis bibliography, nothing more is necessary in the footnote than the author's name. the title, and the page; if it is not contained

in the bibliography, the form must be complete in itself: author, title, imprint. A few suggestions on footnoting are:

1. Number the citations for each chapter in consecutive order, as in this book.
2. Elevate the reference number, both in the text and in the footnote. Do not put a period after it.
3. The initials of the author should be given. In the thesis they should precede the name; in preparing a book, one should follow the requirements of his publisher.
4. Books and publications whose contents fill the covers of the volume should be *underscored*; all parts of books and all magazine articles, newspaper items, etc., should be enclosed in quotation marks.
5. The abbreviation *ib.*, *ibid.* (*ibidem* = the same) signifies successive references to the same source; *l.c.*, *loc. cit.* (*loco citato* = in the place cited; in the passage last referred to) is used to refer to the same source if other references intervene, as is *op. cit.* (*opus citatum* = the work cited). The proper page number should accompany each of these forms of reference. *Passim* meaning "here and there," "everywhere," is employed by some writers, but its use is not recommended in serious research.

Since the placement of citations at the bottom of a typewritten page involves some mechanical difficulty, some method of obviating it is desirable. A convenient way to do this is to set off the reference wherever it occurs by straight lines, and, if a quotation is given, indent it slightly and single space. This practice is acceptable in manuscript prepared for publication. The scheme is illustrated as follows:

The disadvantages of the loose-leaf system of note-taking is well expressed by Headley: [5]

---

[5] Leal A. Headley. *How to Study in College*, p. 338.

Perhaps the greatest disadvantage in the loose-leaf system lies in the danger of getting sheets confused. Against this the proprietor should always protect himself by marking at the top of each sheet a brief notation indicating the number of the page which it represents in that series, perhaps the date, and certainly the reference or lecture to which it belongs.

Library etiquette. Since an extensive use of the library is contemplated, a word or two concerning library etiquette may not be amiss. The coöperative nature of library service should first be recognized. Books are constantly in demand; and the same copy may be used by several hundred different individuals in the course of a year. The librarian has an exacting position. She has to satisfy and reconcile the often conflicting demands of teachers, departments, and students. She is often called upon to teach the simplest rudiments of library use to beginners and to graduate students alike. Prompt, courteous, and efficient service are expected at all times. She has, moreover, a tremendous responsibility for books, building, and equipment.

The graduate student frequently has opportunity to be helpful. He can at the least learn something of library science, and soon reach the point where he can depend upon himself. He can be courteous and considerate. He can return books promptly; he can keep them from injury while they are in his possession. There is no need of marking or underlining passages in books, if one has an orderly note system; and little need of it in any case. Marked books almost always signify the crammer, the undergraduate, the provincial; they have nothing to do with scholarship. The student can avoid misplacing books in the library; if he at-

tempts to restore books to the shelves, he can take care to see that they are correctly placed. He can avoid social conferences in the stacks and in the reference rooms. He can follow library rules to the letter, and, in doing all of these things, he may be sure his research will not suffer as a consequence, nor will he obtain less service from librarians.

EXERCISES AND PROBLEMS

1. Make a bibliography of a selected list of articles on *Research*, from the *Readers' Guide* for the last year.
2. Criticize the following reference for form, in the light of the standards given in this Chapter.
   Blackmar, F. W.: "Leadership in Social Reform"; *Amer. Jour. of Sociology*, XVI: 626–33.
3. Present, in proper form, a critical review (suitable for thesis) of a scientific investigation in the field in which you are interested.
4. Prepare a selected bibliography of ten or more books on *Scientific Method*.
5. To what periodical would you go for material in the general field of mathematics, chemistry, history, education, sociology, psychology, modern language?
6. Verify at least three of the references given at the end of this chapter. If any are incomplete or inaccurate, make the necessary additions or corrections.
7. Using the form contained in this chapter, annotate at least three scientific articles or books in the field in which you are interested.
8. Point out the advantages in arranging periodical references in chronological order. In chronological order by magazines.
9. Examine any book you are interested in, noting the parts title page, copyright, preface, table of contents, body, index, appendix, etc. Does the table of contents explain in detail what the book contains? What is the purpose of the writer?

Is the index reliable? What edition is it? When was it published? When was it copyrighted? Who is the author?

10. Give the names and call numbers of three general reference works.
11. Where would you go for the latest statistics on population in the United States? For financial statistics of cities? For votes cast at presidential elections?
12. Contrast the Dewey Decimal system of library classification with the Library of Congress system.
13. Make out the library slip necessary to obtain the latest work in your library by Karl Pearson.
14. Make out the library slip necessary to obtain a manual of style or style book in your library.

PROBLEM 17

Verification of References

Situation 17: As a regular assignment in *Principles of Research*, Professor Randall asks his students to verify a small number of references. The purpose of this assignment is to discover whether the students are attentive to small differences between the form of the references assigned and the standard, and whether errors can be detected. Back of these aims is the general aim of establishing a habit of verifying all references used.

As an incentive to accuracy, he cites the case of Mr. Walker. Mr. Walker was a candidate for acceptance to candidacy for the doctor's degree. He expected to write his thesis in some historical phases of his major subject. His faculty was reluctant to approve him, because his ability to do careful, accurate research was doubted.

While the case was under consideration, in one of his courses, the question of methods of predicting population arose. The instructor asked the members of the class to find out what they could upon the subject and hand in their references, which he agreed to add to the syllabus. Mr. Walker submitted three cards. In checking these references, the instructor found errors in two of the three.

He, therefore, became more skeptical concerning Mr. Walker's ability to engage in research. He declared that it would be particularly hazardous for such a person to engage in historical research, where the number of references used was large and errors of citation especially serious.

Problem 17–A: Prove that you can prepare reference cards by citing at least five references on the subject of research, and that you can verify citations by checking any five citations in this book.

Problem 17–B: Prove that you can correct references by putting the following in proper form and amending any errors.

Mann, Margaret. "Research in the Special Library"; in *Library Journal*, vol. 49, pp. 726–29. (August 2, 1924.)

Ogg, F. *Research in the Humanistic and Social Sciences.* New York, 1928. Chapter 3.

Blackmar, F. W. "Leadership in Social Reform"; *Am. Jr. Soc.* XVI: 626–33.

Baldwin, James. *A Dictionary of Philosophy and Psychology.* London, 1905.

Channing, Hart, and Turner. *Guide to the Study of American History.* Revised edition.

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Bogardus, E. S. *Making Social Science Studies*, 3d ed., pp. 35–41. Jesse Ray Miller, Los Angeles, 1925.

Cole, George W. *Compiling a Bibliography.* The Library Journal, Publishers, New York, 1902.

Dow, Earle W. *Principles of a Note System for Historical Studies*, chaps. III, V. The Century Company, New York, 1924.

Good, Carter V. *How to Do Research Work in Education*, pp. 205–11. Warwick and York, Inc. Baltimore, 1928.

Headley, Leal A. *How to Study in College*, chaps. XI, XII. Henry Holt and Company, New York, 1926.

Hutchins, Margaret, Johnson, Alice S., and Williams, Margaret S. *Guide to the Use of Libraries. A Manual for College and University Students*, 2d ed., chap. XXIX. The H. W. Wilson Company, New York, 1923.

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Mudge, Isadore G. *Bibliography*. American Library Association, Chicago, 1915.

Oldham, S. R. "A Library Test"; in *The Wilson Bulletin*, vol. 2, pp. 214–15. (April, 1924.)

Park, Clyde W. *English Applied in Technical Writing*, chaps. X, XI. F. S. Crofts and Company, New York, 1926.

Reeder, Ward G. *How to Write a Thesis*, chaps. III. XI. Public School Publishing Company, Bloomington, Illinois, 1925.

Rogers, Walter T. *A Manual of Bibliography*. H. Gravel and Company, London, 1891.

Schneider, Georg. *Handbuch der Bibliographie*. K. W. Hersemann, Leipzig, 1923.

Severance, H. O. "How Periodicals Aid Research"; in *Library Journal*, vol. 53, pp. 590–92. (July, 1928.)

Van Hoesen, H. B., and Walter, Frank K. *Bibliography, Practical, Enumerative, Historical*, chaps. I, II, VII, VIII, XI. Charles Scribner's Sons, New York, 1928.

Wilson, H. W. Publishers. *A Quarter Century of Cumulative Bibliography: Retrospect and Prospect*. The H. W. Wilson Company, New York, 1923.

CHAPTER X

THE MECHANICS OF THESIS WRITING

Mechanical requirements. Nearly all the requirements of thesis making grow out of the problem, and the method used in solving it. However, there are certain specifications which are more or less conventional and uniform in character and they are chiefly important if they are neglected. A very creditable thesis might be written in which few or none of the formalities are met, yet the completed document would fail of acceptance. It would fail because it did not meet the conventions, and because it was not correct in mechanical make-up. These mechanical requirements are not altogether arbitrary; back of each lies, as a rule, some justifiable reason. Margins are required to be wide, so that reading matter will not be covered up when the manuscript is bound; tables are numbered in order to admit of quick reference and to insure proper placing; drawings must be inserted at the proper places; and so with other and similar details.

Parts of the thesis. Although there are many separate items pertaining to thesis mechanics, these may be brought under four headings, namely: (1) form, (2) arrangement of contents, (3) reference, and (4) style. Form has to do with the width of margins, and the nature of the spacing. Arrangement is concerned with the order and relationship of the parts of the thesis. Reference takes up the means used in summarizing and finding the contents: tables of contents, lists of figures and tables, and indexes. Style deals with such topics as the sentence, the paragraph, and proof-

reading. These four divisions will be considered in the order given.

1. *Form in the thesis*

Typing and binding. The thesis should be typewritten, on a good quality of bond paper, $8\frac{1}{2}$ by 11 inches in size. Paper of 16 to 24 pounds weight is acceptable, with 20 to 22 pounds weight preferred. The ribbon should be new and black in color; the carbon copies should be black, and the letters legible — not blurred. Indistinct matter should be recopied. As the original and three copies can be made as easily as two, it is well to make that number the minimum. This will provide one for the registrar's office, one for the main library, one for the department library, and one for the candidate. The manuscript should be as well bound as a standard book, the sheets sewed and glued, and the cover made of strong cloth. While prices in different sections of the country are not the same, the charge for typing will run from fifteen to twenty cents a page, and one cent a page extra for carbons, paper furnished by the student. The cost of binding runs from \$1.50 to \$2 a copy.

Typing should be upon one side of the paper only. The pages should be numbered in consecutive order with the typewriter, or with a numbering machine. Page numbers belong at the top and outside corners of the sheet — the upper right-hand corner of the manuscript. All straight text should be double spaced; quotations, if more than a line or two in length, should be set in five spaces and single spaced. Formulas and equations should be dropped three spaces, centered, and single spaced.

Margins and titles. The left-hand margin should follow a straight line one and one fourth inches from the edge of the paper, to leave room for binding. Marginal notes may be typed in if one desires to do so, though they are usually unnecessary in as distinctly formal and scholarly a piece of work as a thesis. The right-hand margin should be kept at least three quarters of an inch wide. This makes the appearance better, and allows a little space for trimming the edges. With margins of one and a quarter and three quarters, respectively, the typed line will be six and one half inches wide. Top and bottom margins should be uniformly one inch wide, giving nine inches of composition. A page $6\frac{1}{2}$ by 9 inches will carry approximately 250 words to the page. Typing is spaced to run three lines to the inch, hence there will be 27 lines on a nine-inch page. Paragraphs should be indented uniformly, not fewer than five spaces nor more than nine. Five is a good standard, and looks well on the page.

Chapters should be headed with a brief title, dropped at least an inch from the top of the page, and centered. Composition should begin three spaces below the chapter title. If it is probable that the thesis will be printed, the chapter headings should be underlined twice for small caps, three times for large caps. Book titles and matter emphasized should be underlined with a straight line for *italics*. Foreign terms also are commonly italicized. If paragraph or topic headings are used, as in this volume, they should be underlined with a wavy line to indicate that they should be set in **black-face type.**

2. *Arrangement of the contents*

Arrangement. The parts of the thesis are as follows: (1) title page, (2) the certificate of approval, (3) the preface and acknowledgments, (4) the table of contents, (5) the introduction, (6) the body of the thesis, (7) the appendices, if there are to be any, and (8) the index.

1. *The title page* consists of the title of the thesis, the submission paragraph, the name of the author, and the date submitted. The title should be carefully chosen. It should *tell what the thesis is about.* If this can be done in a few words, so much the better, but one should not sacrifice clarity in order to secure brevity. Unnecessary words should be eliminated ruthlessly. The title, *Echoes of Homer in Plato's Protagoras and Republic Derived from a Comparison of Sources* could be deprived of the last six words without loss.

Theses beginning with "An Inquiry into," "A Study of" are modest and adequate. Titles that indicate the method are also satisfactory, as, "An Historical Study of," "An Experimental Study of." Titles beginning with "On," as "On Quintic Curves," "On Children's Interests as Revealed Through Association," are correct, but somewhat pedantic. They hark back to the days of the scholastic debate and the thesis as an essay. Such titles as *Science in Modern Romance, Fusaria of Potatoes,* and *Divorce — A Study in Social Causation* are apt, emphatic, and to the point.[1]

The statement of submission tells to whom the thesis is submitted and for what degree. It is centered, following the title, and is set halfway down the page. A simple form is as follows:

[1] See Chapter II, pp. 37–38.

A THESIS

SUBMITTED TO THE DEPARTMENT OF ....

AND THE GRADUATE COUNCIL OF THE UNIVERSITY

OF .... IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

The bottom of the title page is reserved for the name of the writer, the name of the place, and the date submitted. The material is equivalent to the imprint of a book. The sheet following the title page should contain only blank forms for the certificates of approval, as follows:

Approved for the Department:

....

Approved for the Graduate Council:

....

Next, in order, is the preface, foreword, and acknowledgments: terms, which in the thesis are to a major degree synonymous. In this quite business-like portion of the manuscript the reader should be told when the work was projected, what its purpose is, where the investigation was made, and to whom the writer is indebted for guidance and assistance. This whole section should be reduced to the compass of two or three pages. The first part may be omitted; the last part should not be.

Table of contents. The table of contents should follow the preface. If an index is a part of the thesis, the table need not consist of more than the chapter or section head-

ings, followed by the page citations. If there is no index, the table of contents should be analytic enough to contain the chief subdivisions and the main topics in each section, with page citations for each. A form like that followed in this text (see table of contents) is satisfactory, or a form similar to the one below may be adopted:

CHAPTER II. SUBJECTS, DATA, METHODS

1. Subjects 87
   A. Group A.................................. 88
   B. Group B.................................. 93
   C. Group C.................................. 94
2. Data.. 94
3. Method of Treatment......................... 97
   A. Hereditary and environment factors and interests. 97
   B. The intelligence factor or "brightness".......... 97
   C. Rating of character......................... 112

The titles of tables, charts, diagrams, and figures should be given separately under such headings as TABLES, FIGURES, or LIST OF TABLES, LIST OF FIGURES. The number of a table should precede the title, as:

V. Ratings on Group B, with Means and Standard Deviations of the Individual Raters..................... 102

the figures at the end being the page on which the table is to be found. Charts and figures should also be numbered in order, using Roman numerals for tables and Arabic for figures, and then paged or listed as on or following the page given. As an example, we have:

27. Distribution of 231 Eminent Men By Nationality and Intelligence Quotient............................ 225

in which the last number is the number of the actual sheet upon which the chart is to be found.

If one desires, the title page, certificate of approval, and table of contents may be paged separately, at the upper right-hand corner, or they may be paged consecutively as a part of the thesis proper. If separate paging is followed small (lower case) Roman numerals are used. If a numbering machine is available, the single consecutive type of paging is the better. Under this plan, the title page would be page 1.

The thesis introduction. Omitting from consideration the accessory parts of a thesis, such as table of contents, appendix, and index, there remain three parts: (1) the introduction, (2) the body, and (3) the conclusion. Under these three parts may be brought the items listed by Hill as essential in a report of research: [2]

> One has a right to expect that: (1) the subject of research shall be clearly stated; (2) scope and aims shall be clearly defined; (3) the materials used and the procedure followed in making the study shall be clearly described; (4) the data, including tables, graphs, accompanying explanations, etc., shall constitute the body of the report, and objective facts shall be kept separate from statements of personal opinion; (5) if a summary and conclusions are included, unusual precision and succinctness of statement are desirable; and (6) the references or bibliography shall be relevant.

The importance of the introduction should not be ignored. It is the means of making the reader acquainted with the problem — of leading him into it — and it serves, too, to orient the investigator. In many theses, the introduction may be written before the investigation is commenced; in all theses, that part of the introduction which leads up to a statement of the sources used in solving the problem should

[2] D. S. Hill. "Application of Research in Relating Industry and Education," p. 10.

be put into perfect written form as a preliminary to the scientific work.

The introduction properly begins with the history of the problem. This history should contain a review and a summary of all related scientific investigations, with comments of a critical nature on their merits and limitations. The history should be followed by an explanation of the relation of the problem to the preceding investigations. How did it arise? How does it grow out of the past? What is its present significance? These are the questions to be answered. The third step is to make a clear statement of the problem, following the statement with definitions of any terms whose meanings are not commonly known, or which are used in the report in new, particular, or highly technical ways.

After the definitions comes the analysis of the problem, with a statement of the issues to be resolved or the hypothesis to be tested. Last of all, the sources or subjects should be briefly described, and a few paragraphs should be given to explaining the method followed. The accounts of the sources and method will of course be amplified later; in the introduction the purpose is to picture the outlines of the study. No time should be taken to show sketches of apparatus, make a critical analysis of the sources, or describe the subjects in detail. The detailed description of these belongs in a separate section or chapter, where the treatment can be complete and adequate.

The body of the thesis. The first section of the body of the thesis should take up in detail the sources, subjects, and method by which the data were derived. This section

should be clearly written, and should be well illustrated with diagrams and photographs of apparatus if new types of apparatus have been necessary. The subjects should be described in detail, until so clear a picture of the situation is drawn that another investigator would, without difficulty, be able to reproduce it.

This section should be followed by the data. The data in the historical thesis are comprised in the running narrative; in the experimental and the normative theses they are condensed into tables and charts. The raw data (individual measures, documents, etc.) belong in the appendix. The body should, therefore, contain classified data, with a running description or narrative to bring the tables into the form of an orderly discourse. No table should be omitted from mention in the description. If it is, the thesis is incomplete. Practically what is done is to give data in tabular form in experimental and normative theses, and then to recite the same facts in the accompanying scientific description. A table may be cited merely for details, but to offer, as a thesis, a disconnected collection of tables is not to prepare a thesis at all.

Form of tables and charts. Certain conventions apply to the form of the tables. The number should come first, in Roman numerals, as: TABLE V, TABLE VI, TABLE VII. After the number should come the title, which should be reasonably brief — say, no more than two lines. If more explanation is needed to enable a reader to understand the table, an asterisk should be attached to the title and the supplementary information supplied below the table in a form of footnote.

Two spaces below the title, a horizontal line should be typed across the sheet. Below this line should be given the notation for the columns. Another line is then typed, the data are presented, and after the data is placed an end line. Two admonitions are usually needed in preparing tables: (1) always put the title of a table above it, because one reads a table from the top downward; and (2), never put more than one kind of data in a table, or the table will fail to make a clear impression. Vertical lines separating the columns are desirable, but not absolutely necessary.

Charts (figures, diagrams) serve two purposes in theses: (1) to present data graphically, and (2), to illustrate tabular data: i.e., to make the meaning of the data clear. These purposes should be distinguished, and the two types should be appraised by different criteria. For example, let us assume that the purpose of a chart is to present data graphically. It probably offers, within the space of a half-page or a page, facts which would cover ten to twelve pages in verbal description, and at least a page in tabular material. Such a chart should be judged by its accuracy, completeness, and appropriateness, rather than by the ease with which it may be read, though, as in the case of tables, it should be a unit.

Illustrative charts are to be judged by their appropriateness and by their success in making tables clear. A reference should be made to the data they represent by stating, after the title (to illustrate Table VI, etc.). In general, charts should be uniform in size and style. All charts should be permanent, which means they should be made with India ink, or printed. Pencil, fountain-pen ink, water colors, and pastels are not satisfactory for making charts and

illustrations. The color of the ink is unimportant, but preference is given to black and green. Red ink signifies non-standard or unsatisfactory conditions. Charts should be made on a good quality of ledger drawing paper. Cross section paper is often accepted, but usually charts on this paper look amateurish.

Charts, partly to distinguish them from tables, should be designated by Arabic numerals. The title should be brief but definite. Both number and title should be written below the chart. The reason for this is that the point of reference of a chart is the lower left-hand corner. This is the place from which reading begins. The information the reader needs: number and title are placed near the point of reference. It is a good idea to box a chart in, as it is then plainly set off from descriptive matter.

The conventions of chart-making may be found in any good book in graphic methods, such as Haskell's *How to Make and Use Graphic Charts* (Codex Book Company, Inc., New York, 1919) or Williams's *Graphic Methods in Education* (Houghton Mifflin Company, Boston, 1929). The directions should be followed literally, because the charts are a part of the thesis — a work that presumes to be scientific. Any departure from accepted standards detracts from the scientific character of the product. Only the original drawings have to be made in India ink. Photostats may be obtained from the ink drawings at much less expense than the duplication of the originals. Photostats are quite satisfactory in representing flat surfaces, such as drawings and documents, but they do not bring objects into relief, and hence are not suited to the reproduction of objects. The

negative of the photostat should be retained, and prints from it procured for the thesis.

Interpretation and principles. The last section of the body of the thesis should present the generalizations growing out of the data. As has been said, the principles will be either a norm, a law, or an historical generalization, which is merely a statement of the truth of the hypothesis set up in the beginning of the thesis. If the principle is related to any general theory, the relation and its significance should be shown.

The conclusion. The section called the conclusion is supposed to accomplish four things: (1) a summary, (2) a statement of the contribution, (3) a statement of limitations of the study, and (4) suggestions for further investigations in the same field. The summary is simply what it says it is — a brief review of the entire work, from the problem to the principle. Necessarily, the proof is not repeated, else there would have been no need of giving the data in the body of the thesis. No definite limits can be set to the summary, but generally it is not sufficiently condensed if it covers more than five or six pages.

The discussion of the contribution affords the investigator an opportunity to present his case. Has an addition been made to knowledge? If so, what? Have new techniques been evolved? If so, what are they? Has new material, not heretofore available to the many, been made available? If so, what is it? Are the results useful? If so, in what way can they be applied? These are the kind of questions to treat in this division of the thesis.[3] In any

[3] The statement is repeated that an investigator does not need to prove

event, the claim ought to be a modest one; it is more dangerous to claim too much than not enough. Next to truth, modesty is the reigning goddess of the scientist.

The limitations. Perhaps the last remark explains as well as it can be done why a discussion of the limitations of the study is advised. In this section should be presented conditions and circumstances which prevented the study from being as perfect as could be wished. A Were some factors unaccounted for? B Did some disturbing element appear which may have influenced results? C Are there phenomena unexplained and unaccounted for? D Are there contradictions? E Do the results obtained agree with the findings of other investigators? F Were the sources inadequate, invalid, unreliable? G Were the subjects too few, or poorly selected? Was there a lack of time, money, apparatus; were measuring instruments lacking in precision? What modifications would be introduced if one were studying the problem again?

Finally, the investigator should take seriously his obligation to enumerate related subjects for further study. In a sense, this is a test of whether he has profited by his research experience and of whether he has promise as a scientist. To a lesser degree, it is a measure of the fecundity of the field. He should therefore set down a small and well-selected number of closely related problems, giving preference to those that have grown out of his own study. If he has definitely decided to attack one or two himself, he should indicate which they are.

that his thesis is useful in order to prove it a contribution, but the evidence of usefulness attracts some minds, and may help to balance the scales to some degree in his favor

The appendix. Raw data, and documents not readily accessible, are placed in the appendix. They are assembled to: (1) supply a check upon the reliability of the thesis, and (2) to make material convenient for future use. Each section of the appendix should be placed under a heading that tells exactly what is included. Each section should have a number, and each should be listed by number and title in the table of contents. The body of the thesis can be kept from being too bulky by taking tables from it, but all such tables should be placed in the appendix.

The index. Theses are seldom indexed, because a single topic is treated, and it may be presumed that if a reader is interested in part he is interested in the whole, or that the parts are so clearly indicated in the table of contents that any one may be found easily. If, however, the thesis is likely to be much used; if it is literary or historical; or if it is complex, technical, or bulky, an index will be found helpful. If a complete index is not supplied, a list of the chief topics may be arranged, in alphabetical order, to supplement the table of contents.

A thesis index is quite easily prepared. Using cards, three by five, the first topic or term of importance on the first page is entered. After the topic, is put the page number. This is done for every subsequent topic until all are entered, only one topic or term to a card. Names of persons, places, formula, principles, and the chief concepts cover most of the items to be listed. After the cards are ready, they should be alphabetized, duplicate terms thrown out, and all the page numbers referring to the same term entered on one card or sheet. The next task is to classify, by putting like

terms under a common heading. When this is completed, the cards should be copied.

3. *The style of the thesis*

Style. The first question usually asked about style is how much to write. This question may be answered indirectly, in the following way. The most important principles of style are *accuracy*, *force*, and *charm*. Accuracy means *say what you mean*, force means *say it so you will be understood*, and charm means *say it so your reader will agree with you.* One should attempt to realize these ideals and forget volume, though, in so far as there is a rule on the subject, it is "keep the thesis down to the minimum. Avoid padding and ornate writing. Be direct."

James Barrie has said that the man of science appears to be the only man who has something to say just now — and the only man who does not know how to say it. Rickard passes a similar criticism, saying:[4]

> Indeed, the engineer does bungle language deplorably. He makes a fetish of efficiency, yet he shows no regard for the effective use of one of the most important tools — the pen; he believes devoutly in accuracy, yet he employs a weapon of precision as carelessly as a small boy handles a gun.

Ruskin warns against being over-technical. It is his opinion that "a great part of the supposed scientific writing of the day is simply bad English, and vanishes the moment you translate it." Rickard cites an example of over-technical writing, from a description of the Mount Morgan lode in Australia, which he terms "Metamorphosed pseudomorphic after flapdoodle":

[4] T. A. Rickard. *Technical Writing*, p. 1.

It may be considered as consisting of a network of veins, traversing on the one hand a metamorphic matrix of somewhat argillo-arenaceous composition, and on the other hand what appears to be a feldspathic tufaceous igneous rock.

The point is more telling in the story of an educated engineer, who made this report to his manager:

"This morning I went over to see a new machine we have at our place, and it's astonishing how it works."

"And how does it work?" he was asked.

"Well," was the reply, "by means of a pedal attachment, a fulcrumed lever converts a vertical reciprocating motion into a circular movement. The principal part of the machine is a huge disk, which revolves in a vertical plane. Power is applied through the axis of the disk, and the work is done on the periphery, and the hardest steel may be by mere impact reduced to any previously determined shape."

"What is this wonderful machine?" asked the manager.

"A grindstone."

The sensible thing is to have one's readers in mind, and then write on the level of their ability and understanding. In the thesis itself, the student is not to be criticized if he writes so that the matter is intelligible to specialists in his particular field. A better standard has been achieved when the matter is understood by all who work in the general field with which his specialty is related. To illustrate, if his specialty is amino acids, the minimum standard is that his thesis be understandable by specialists in amino acids; but he has proved himself a better writer when he makes the thesis understandable by all chemists. Even a better level to aim at would be scientists in general.

This principle applies equally well if the writer is preparing a manuscript for publication: *adjust the content to the*

reader is a rule of importance. For the technical magazine, the composition may be technical; for the superior layman, it may be reduced a considerable degree in difficulty; and for the general layman, it must be couched in simple, concrete, and well-used terminology. One who says what he means so that those he says it to can understand his meaning, need have no concern over whether his words are technical or common. The trouble comes when he writes over the heads of his readers, or superciliously makes clear that he is sacrificing his standards by writing down to them. One should remember, too, that a thesis is not an oration or a literary essay, and that the writer is under no obligation to copy the style of De Quincey or Edmund Burke.

The sentence. No intention exists to write a dissertation here on sentence structure, but to remind the student that if accuracy, force, and charm are to be attained in the whole they must appear in the parts, and of the parts the sentence is the simplest and most fundamental. Judging by the extent to which the rule is violated, there is nothing trite in saying that every sentence must have a subject and a predicate, and, except for titles, groups of words which do not contain these requisites should be weeded out of the thesis. Second, the writer should ruthlessly eliminate all conjunctival terms, such as *and* and *but*, standing as the first words in sentences. Conjunction means act of connecting or joining to, and this meaning is utterly lost if the word is used to introduce a sentence. A third good suggestion is to make the subjects the actors, which is only another way of saying avoid the passive voice.

Force likewise may be obtained by refraining from begin-

ning sentences with the *impersonal* pronoun *it*, as: *It was observed that the experiment was a failure.* Ask yourself, "What is the antecedent of this pronoun? Does it give strength to the sentence? Does it add to the meaning?" Other words to be used sparingly as initial terms are *with* and *while*, and even the indefinite *one* which is sprinkled rather too frequently through these pages does not bear a very good character in an introductory position. Doubtless the best single rule for a beginner to follow is this: make the sentences short, but complete.

The paragraph. From the structural point of view, the paragraph is more important than the sentence. Any section of a thesis (the introduction, the body, the conclusion), or the whole thesis may be compared in form to a freight train. The locomotive is the *raison d'être*, the cars are the paragraphs, the caboose the goal. To make a real train, the cars must be connected with each other and to the locomotive and the caboose. The sentences, with some stretch of the imagination, supply the cargo for the cars, that is, the paragraphs.

Every paragraph has a subject if it is a true paragraph. This subject is the topic sentence. It may be the first sentence, the second sentence, or the last sentence, but, unless it is actively present, the paragraph is a name only. The topic sentence should be short and clear, and, although any position is correct, until facility in paragraph construction has been developed the best thing to do is to put it first. For the closing sentence, either a summarizing sentence or a sentence that points ahead, is appropriate.

Connection between consecutive paragraphs may be ob-

tained in several ways. Time order is a great help; there is then a first, a second, a third, and so on. Connection is therefore easier in history than in descriptive, argumentative, or expository writing. In these types, dependence is had upon place order, simple to complex order, cause and effect order. Terms used to show connection are *next, then, therefore, whereas, since, hence, nevertheless, as a consequence, however*, and the like. Terms like preceding and following, and their respective synonyms, also help tie paragraphs together.

The function of the paragraph is to help the reader. It should, therefore, not be too long; in fact, with experience, the writer should make each paragraph carry approximately equal parts of the loading. A long paragraph is likely to be, not one, but two or more; a very short paragraph is likely not to be a paragraph at all, but a collection of unrelated sentences. To write a good paragraph remember to have a topic sentence, connect with others, close it with a summarizing or reference sentence, and keep the length uniform and not very long.

The person. In preceding chapters, science has been described as objective and dispassionate; and the impersonal objective attitude has been mentioned as essential in the scientist. This spirit is indicated by the kind of pronouns which are appropriate in scientific writing, the rule being, *Write in the third person, only.* In a short article on the nature of intelligence, published a year or two ago, the pronoun *I* appeared thirty times — about five times to the page. The article was made up of opinion, reënforced by the writer's striking the sounding board of *I* as often as he

could get an excuse to do so. It was not modest; it was not scientific; it was slightly nauseating.

Such pronouns as *I*, *my*, *mine*, *our*, *ours*, *we*, *us*, and *me* should be eliminated from the thesis vocabulary. If they are tolerated at all, the writer tends to slip into such expressions of opinion as: "I think," "I believe," "I feel," as if the connection of the pronoun gave some peculiar potency to the unscientific term which follows it. The editorial *we* is fully as objectionable; it has an oily, flattering sound, that suggests a desire to evade full responsibility for what is said, such as the "We have heard," and "We suspect" of the old-fashioned newspaper man. If forced to refer to self, use *the writer*, *the experimenter*, *the investigator*. Only in the preface is the first person permitted; the remainder of the thesis should in common decency be written in the third person.

Reading proof. The meaning of the saying, "No man is a hero to his valet," is known to every one. To the thesis writer the saying, "No man is able to pass judgment upon his own work," is even more pertinent. After he has read his manuscript, made alterations, corrected errors, and rewritten it anywhere from one to five times, it should be put into the hands of a competent proof-reader to check errors which the writer, somewhat blind to his own mistakes, has overlooked. No matter how competent he feels himself to be, no matter how sure he feels that there are no misspelled words, no omissions, and no grammatical mistakes, a keen-eyed reader is almost sure to prove him wrong. Though textbooks are proof-read by trained readers time and time again, scarcely a book comes from the press that does not

contain a few errors, apparently quite obvious ones, in the finished work.

Although proof can be read on a thesis without knowledge of proof-readers' marks, there are many reasons why one should learn them at this juncture. They are simple, convenient, and time-saving. The knowledge, too, will be useful later on when the thesis is published, and the author is called upon to correct the proof. The list of marks suggests more things to be attentive to than the inexperienced reader is likely to think of, and in this sense helps to improve style and form. The marks are, therefore, given here for reference when needed:

MARKS USED BY PROOF-READERS

	Delete and close up	en|	En dash
	Reverse	;|	Insert semicolon
	Close up	(:)	Insert colon
#	Insert space	⊙	Insert period
¶	Paragraph	?|	Insert interrogation point
□	Indent one em	(?)	Query to author
[	Move to left	⌒	Use ligature
]	Move to right	(sp)	Spell out
⊔	Lower	tr	Transpose
⊓	Elevate	wf	Wrong font
∧	Insert marginal addition	bf	Set in bold face type

∨∧	Even space	rom	Set in roman type
×	Broken letter	ital	Set in *italic* type
⊥	Push down space	caps	Set in CAPITALS
═	Straighten line	sc	Set in SMALL CAPITALS
‖	Align type	lc	Set in lower case
∧,	Insert comma	/	Lower-case letter
∨'	Insert apostrophe	stet	Let it stand
∨"	Insert quotes	no ¶	Run in same paragraph
=|	Hyphen	ld>	Insert lead between lines
em|	Em dash	hr #	Hair space between letters

All corrections on the proof should have corresponding marks in the margin to attract attention. Superior marks, letters and figures should be indicated thus: ∨', ∨r, ∨2, or ', r, 2. Inferior marks, letters, and figures should be indicated thus: ∧,, ∧r, ∧2.

The student is amply repaid in many ways for his care as to the mechanics of thesis writing. In the process, he acquires standards of workmanship, which contribute to his later success as a writer and scholar. His thesis stands as a permanent record of his ability as a student, and it is well if he can feel as proud of it twenty years after as at the date of its completion. He need not deceive himself with the belief that form and arrangement and style will compensate for inferior research. Dress does not make the man, but it contributes to his success. Last of all, a reasonable concern

over craftsmanship will protect him against taking refuge in the time-worn excuse of mediocrity: "I put all of my time on the research; I do not care how it is expressed." This is simply a defense-reaction with which the realist will have nothing to do.

Summary. Since the thesis is a formal production, there are certain conventions to be met. These pertain to form, arrangement, reference, and style. The parts of a thesis in order are the title page, the certificate of approval, the foreword, the table of contents, the introduction, the body, the conclusion, and the appendix. The introduction states the problem, reveals the sources, and outlines the method; the body gives the data and the resulting principles; the conclusion includes the summary, the contribution, the limitations, and the further problems for study. The appendix contains the raw data.[5]

EXERCISES AND PROBLEMS

1. Sketch through a thesis hastily, and see if you can find any errors in it in spelling, omissions, grammar, sentence structure, etc.
2. Examine a few paragraphs in this book to see if they have topic sentences. How would you describe the sentences: as long, short, medium, variable?
3. What is contained in the title page of this book?
4. Collect the titles of five or six theses, and criticize them.
5. Examine the figures and tables in a thesis. Are they numbered? Are the titles properly placed?

[5] The bibliography is properly placed between the conclusion and the appendix. Inasmuch as its arrangement was discussed in Chapter IX, further treatment was not considered necessary here.

6. Explain why any charts, graphs, and figures used in a thesis should conform to the conventions.
7. Criticize the conclusion of a thesis in the light of the discussion on pages 263–64.
8. Give reasons why a thesis should be impersonal: i.e., why pronouns of the first person should be avoided.
9. Explain why an analytic table of contents is desirable in a thesis.
10. Why should the writer avoid beginning sentences with the impersonal *it*, with *while*, with *and*, or with *but?*
11. Show how paragraphs may be connected with each other in the thesis.
12. What are the answers to the questions whether one should use technical terms or not, write simply or not?
13. Examine any standard style book, and report what is to be found within it.
14. Is a preface necessary to a thesis? What should it contain? What is contained in the preface to this book?

PROBLEM 18

Reading Galley Proof

Situation 18: Mr. Prescott has sent an article to the *Journal of Science.* The article has been accepted for publication, and has been set up. Mr. Prescott has just received galley proofs, a portion of one page being reproduced below.

Problem 18: Read proof on this section, and make corrections as you would if you were returning the proof to the printer.

In *The Californai Sardine* a publication of the State Fish and Game commission the statement is made that there are three main fishing portts along the Coast, Monterey, Los Angeles, and San Diego. And the statement is made also that natural abundance fo fish in particular areas, with lack of fish in ohter areas do not explain the location of the canneries. The

supply prob ably will not be exhausted as a result of the fisheries.

And with improevmtn in taking fish and better marketing conditions for the product, not only permanence but increase is liketo to be expectedd etaoin shrdlu . . . .

This conclusion is borneout by experience in fisheries of the old world. Although the size and quantity of the catch are variable from period to period fishing does not seam to exhaust the supply. The question is one of economics as well as of biology — and not all the issues have been cleared up. Nevertheless the conclusion is sound that nothing points to the diminishing of the sardine supply and that conditions are favorable to increase from year to year.

The date at which the fishin seasn opens and closes varies from year to year. Commencing normally in July, it continues normally until around the first of march. The beginning and duration of the season vary a month or so from year to year probably due to economic rather than because there is any shortage of fish. There has been a tendency to increase the length of the season in recent ye rs and further increase is not at all improbable

PROBLEM 19

Judging a Part of a Thesis

Situation 19: Mr. Gordy had just presented his thesis to his adviser. Since his adviser had kept in close touch with the progress of the research and the results, he was quite well informed already on every point except the way in which the thesis was presented.

He therefore proceeded to make suggestions which had to do in the main with the mechanics. His chief criticism centered upon the conclusion, which was, he declared, incomplete. He objected to the generalizations, on the ground that they were conclusions, not principles.

Mr. Gordy is confronted with the task of rewriting the section known as the conclusion.

Problem 19–A: Examine the conclusion of a thesis in which you are interested, and criticize it in light of the suggestions given in the text.

Problem 19–B: Rewrite any part of the conclusion which is inadequate: that is, supply what is necessary to make it complete and correct.

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CHAPTER XI

STANDARDS OF RESEARCH AND THESIS

Judging the thesis. The judging of a thesis is itself a problem of normative science. When the work has been completed, and before the candidate is recommended for the degree, some one must decide whether or not the thesis is acceptable. The continuance of the requirement depends, too, upon the conviction that it succeeds in giving training in research and that it instills into the candidate something of the proper scientific attitude. Although the judgment on both these points is ordinarily rendered in such an unscientific way that it is little better than opinion, the fate of the student, so far as his degree is concerned, depends on the report of the individual or the committee with whom the decision rests.

Usually one person decides the fate of the master's thesis, subject to the veto of the graduate council. The individual with whom the decision rests is usually the adviser. For the doctor's thesis there is generally a special committee, of whom the adviser may be one, to pass upon the thesis and to submit the candidate to a comprehensive oral examination. The question to be considered now is, "Upon what points is a thesis to be judged, and what points are to be considered in further estimating the candidate's research ability?"

Points in judging a thesis. Since the mechanics of the thesis have already been taken up, they will not be con-

sidered further in this connection. There remain, then, four chief topics to consider: (1) the thesis as a contribution, (2) the thesis as an original production, (3) the thesis as a scientific product, and (4) certain personal factors pertaining to the candidate, particularly those that reveal his attitude towards science and research. The first topic to consider, then, is the thesis as a contribution.

1. *The thesis as a contribution*

What is a contribution? Every thesis *should* be a contribution, and, if it is a doctoral dissertation, the regulations plainly specify that it must be so. The question arises, therefore, "What is a contribution?" In answer, it may be said that usually it is granted that a thesis may be a contribution: (1) to knowledge, (2) to technique, or (3) to both. To be a contribution to technique there must be proof of a new instrument of precision, or a significant increase in the precision and convenience of an old one. Within limits, any new use of old devices and procedures is a contribution, as when statistics is applied to an historical problem. The limits prescribe that the results (generalizations) must be more reliable. This principle can be stated, as follows: *Any device or procedure which increases the reliability of results is a contribution.*

A contribution to knowledge may be made by adding a new principle — a norm, a law, or a historical series. As has been said, the candidate need not concern himself about the usefulness of the knowledge; if it is a new principle, the thesis is a contribution. Perhaps it should also be granted that one who brings new facts under an old principle makes

a contribution. The outcome of recognizing such a policy is that any newly derived and properly classified data constitute a contribution. Nevertheless, the conclusion seems sound that (1) a new technique or device, (2) a new principle, or (3) new facts under an old principle, is each a contribution.

Occasionally, a fourth type of contribution is instanced, as the making available to the many what was before available only to the few. Those who believe a contribution may be made in this way give as illustrations the translation of a rare book, or the collection and classification of data from documents difficult of access. The statement is sometimes made that unless this fourth type is accepted as deserving there is no chance of making a contribution by means of the historical thesis. However, in Chapter VII the conclusion was reached that historical data can be brought under a general principle, the same as any other data, and that therefore no fourth type is needed to justify history as science. This fourth principle is a justifiable defense if one's historical thesis is attacked on the ground that it is not a contribution.

2. *The thesis as an original production*

Characteristics of originality. Although an M.A. thesis must be a contribution, it does not have to be an *original* contribution. The specification of originality applies only to the doctor's dissertation. Originality is highly desirable in the M.A. thesis. To be original, the results must not have been derived by any one else. They must be new. A Latin student wrote a thesis on the term, *et*, to find, when

the work was completed, that another student had completed a thesis on the same subject, with identical results, a few weeks earlier. He therefore could not make an *original* contribution.

The originality of a thesis is hard to discuss apart from the originality of the person producing it. Originality is not a trait which lies fallow for twenty-five years, blossoms out in a required thesis, and then returns to the resting stage for the remainder of the candidate's life. There are signs of it along the way; it is not content with a single product, and seldom content with a product in a single field. Some of the characteristics of originality are worth mentioning.

Woodworth [1] mentions such qualities as: (1) intense absorption in the task of creation, (2) amazing speed of production, (3) great productivity, and (4) tendency to specialization. He believes that "the original genius often shows originality in more than one field, and the reason why he does not reach a high level of production in more than one is largely lack of time." [2] Originality also appears early; note in proof such original characters as Alexander, Goethe, Bryant, Cæsar, Newton, Faraday, Helmholtz, Darwin, Shakespeare, Galileo, and Beethoven. This indicates that originality does not appear suddenly later in life in response to a demand — i.e., a thesis.

Factors in originality. Since science in all its forms represents achievement, objectivity is an essential factor in originality. A person whose gaze is habitually turned inward is not likely to be distinguished for any marvelous

[1] R. S. Woodworth. *Dynamic Psychology*, chap. VI.

[2] *Ibid.*, pp. 129–30.

scientific discovery. Reality should be the chief concern; one who deals with things is more likely to exhibit originality in research than one who is dreamy and speculative. The possession of a progressive point of view is desirable, but this is not an unmistakable sign of creative ability, for, as Woodworth says, a person may be original in attitude but not in achievement. *Extroversion*, as distinct from *introversion*, concern with reality rather than with ideas, and action rather than speculation may be looked upon as marks of scientific ability.

A strong natural bent in favor of certain special kinds of materials is another sign of originality. Agassiz had a strong interest in fishes, Newton in mathematical formula, Lyell in earth forms, Faraday in physical apparatus, and Davy in gases. The great artist is irresistibly impelled to occupy himself with color, the musician with harmonious sounds, and the poet with rhythm. The person who feels a strong "pull" or attraction towards any particular field or subject should follow it if he wishes to do research, for there is the best chance for him to display originality. Lack of interest is the death of originality.

Woodworth calls the maxim, "Necessity is the mother of invention," a half-truth. The necessity, he says, must be felt, but not too dire, since under the pressure of dire necessity the tendency is to respond in habitual ways. The necessity which drives a graduate student to originality should come primarily from the inside; it should be internal, not external. This inner necessity is not pain, desire for revenge, hunger, sex, nor any of the other common forces; it is the passion and love for the thing for its own sake, a

natural delight in the research process.[3] It is probably not, as James Harvey Robinson suggests, a desire to prove some one else a liar.

Woodworth gives four qualifications for the original thinker:[4] he should be equipped by past experience and training for dealing with the kind of material he proposes to use, he should be a keen observer, he should have a flexible mind that prevents him from falling into habitual ways of acting, and he should be able to control his mental processes so that he does not digress from the central objective. To this list the writer wishes to add two others: that he be critical of assumptions of all kinds, and that he be persistent in formulating hypotheses about matters which come to his attention and which may offer him problems of research. Ability, plus criticism, plus practice, are the guarantees of original conduct.

The mental and personal traits of the scientist have been investigated by Catherine M. Cox.[5] Taking 100 as the norm of intelligence, she distributes the intelligence of 39 scientists roughly as follows: 10.3 per cent 100–115; 38.5 per cent 120–135; 46.2 per cent 140–155; 2.6 per cent 160–175; 2.6 per cent 180–200. The norm of the group is about 120;

[3] In performing experiments the writer and his students have found that imitation results from two conditions: (1) when the objective is not seen by the subject, and (2) when the subject is not given definite directions to improve upon the pattern or standard. If these principles are sound, the student with the task of preparing a thesis before him should early get a clear view of the end, and should be motivated with the idea to excel. This agrees closely with Burnham's prescriptions for mental health: a task, a plan, and freedom to execute it.

[4] *Op. cit.*, pp. 146–47.

[5] *On the Early Mental Development of a Group of Eminent Men*, p. 254.

the minimum often set for success in college as colleges are now organized; that is to say, nearly fifty per cent of these eminent scientists might have failed in college. The philosopher group exceeded the scientist group in intelligence. Although the number and data do not warrant a general conclusion, apparently originality is not dependent wholly upon general intelligence.

On four non-intellectual traits, scientists rated as follows, social .9, balance 2.1, emotional .6, and persistence 1.9. Philosophers rated: social 1.0, balance 1.3, emotional .6, and persistence 2.0. Obviously scientists are well-balanced, persistent, and non-emotional. Persistence was the outstanding characteristic of all men of eminence studied by Miss Cox.

Varied views of originality. There is a fairly well-defined view that there is no such thing as a new world, a new life, a new art, or a new principle. Those who take this point of view hark back to the time-worn maxim, "There is nothing new under the sun." People waste their time, it is said, in their search for originality — all that is necessary is for a man to be sincere and to try honestly to improve upon what has gone before.

An exactly opposite point of view is also held. Martin believes that "if we reject originality we put an end to progress." The history of the world is the history of its original men. We cannot accept the doctrine that there is "nothing new under the sun," for every custom, everything we have was new once, and had to be originated. This writer believes that "a man's worth should be based on what he himself does—not on what he borrows from others."

Effort has been made to reconcile the differences. The man who is most likely to be original, it is asserted, is not he who in mistaken independence lays claim to a lawless spontaneity of production unrelated to the total yield of human effort, but the man who "goes forth armed with the whole power of the race." Thorndike[6] says that originality must not mean weakness in doing routine work in old ways, or any essential dislike of traditional knowledge or customs as such, or any paucity of fixed habits; but strength in doing work that is new or doing it in new ways, an attitude of hoping to change knowledge or practice for the better, an organization of habits that causes their progressive modification.

To be critical, a person must have an adequate mastery of the field in which he proposes to work. Thorndike puts considerable stress on ability to take care of routine. He made a series of investigations on the ratings of electrical engineers employed by the Westinghouse Company, and found a high correlation between originality and everyday industry. He argues for depending upon routine for ordinary tasks, and for the application of energy thus conserved to original work of a very special type. He defines originality as "reasoned dependence" on other men's ideas. With these views the writer fully agrees. The man who prides himself upon being different may not be original at all; he may merely be ignorant.

[6] E. L. Thorndike. "Education for Initiative and Originality," pp. 405–16.

3. *The thesis as a scientific product*

The essential elements. Inasmuch as the elements of scientific process and results have been explained in preceding chapters, it remains here only to repeat the essentials in order that the reader may have them close at hand to check his own thesis.

The *first* essential is that the thesis begin with a problem; the *second* that an hypothesis be formulated for its solution. If there is no hypothesis, stated or implied, then whatever the product may be it is not a thesis. It is either too much, not enough, or not a scientific product at all, and should either be rejected or reformed.

Third, the thesis must possess validity, which simply means that it must be what it purports to be. There is no argument here that validity should be established in any particular way by statistics, oath, or affirmation, but the connection between what it is and what it is said to be must be one of identity.

Fourth, the thesis must be reliable. The findings should be accurate, and such as any competent person would find if he were to study the same sources by scientific methods.

Fifth, the method employed must be either normative, experimental, or historical. There is no need for combining methods; to do so detracts from the unity of the work. Instead of a single thesis, there may be two or more. There can be no argument whether one or the other is better — the only question about method that can possibly arise is whether the method used is the one best suited to the problem, the sources, and the purposes of the investigator.

Sixth, the final result must be a generalization. This generalization may be history, a norm, or a law. The history, norm, or law need not, in the case of the master's thesis, be original, but original data should be the basis of the thesis, whether a new principle results or new data are brought under an old principle. The thesis does not call for interpretation as an absolute requirement, but its meaning is that much clearer if its final principle can be brought into relationship with the body of scientific theory.

Checking schedule for a thesis. In order to help the student appraise his own product, the simple checking device reproduced on the opposite page has been prepared. No values have been assigned; it is not a measuring stick. The assumption is that, if any requisite is not checked as present, the thesis is not acceptable until the shortage has been made good. Either the master's thesis or the doctor's thesis may be checked by this device, keeping in mind that universities do not usually require originality in masters' theses. Using a similar form, Tvedt and Waage checked 299 M.A. theses at Stanford University (1929). The correlation between the estimates was found to be $.63 \pm .08$.[7] The writer has found that the device can be used for grading on a five-step scheme, A, B, C, D, E, with not more than one step difference between the graders in 98 per cent of the theses.

Bixler has developed a *Check List for Education Research*, applicable to research in any field, and intended, according to the author, "as guides during the process of research rather than as an instrument to be applied at the completion

[7] Carl W. Tvedt. *An Analysis of the Master of Arts Thesis*, p. 3.

Checking Schedule for Thesis

Factors Considered in Checking	Check	
I. The thesis is a contribution	...	...
1. To knowledge, truth or	...	...
2. To technique or method or	...	...
3. Knowledge made available not before available	..	...
II. The thesis is original	...	...
4. In data and principle or	.	...
5. In technique or method	..	...
III. The method is scientific	..	...
6. Normative or	..	...
7. Experimental or	..	...
8. Historical	...	...
IV. The results are scientific	..	...
9. A norm or	...	...
10. A law or	..	...
11. History or	..	...
12. New data brought under an accepted principle	. ..	...
V. Requirements of the research process have been met	...	...
13. There is a problem	...	. .
14. There is an hypothesis	. .	...
15. The tests of it are thorough	. .	...
16. The sources are valid	. ..	...
17. The data are reliable	. ..	...
VI. The mechanics are correct	...	..
18. The literature has been reviewed	. .	...
19. The introduction is complete	...	...
20. There is a table of contents (and an index if needed)	...	..
21. There are no typographical and grammatical errors	...	...
22. The charts and tables are in proper form	...	...
23. The conclusion is complete	...	...
24. The bibliography is adequate and in proper form	...	...
25. The form, arrangement, and binding are correct	...	...

Directions: Put an X after every requirement which has been met; put a 0 (zero) after every requirement that needs further attention.

of a research."[8] Brooks[9] states that "Any piece of . . . research is evaluated according to several standards, of which the following are the most important: (1) the exact determination of the problem, (2) its thoroughgoing analysis, . . . (3) its historical background, . . . (4) the selection and use of the method . . . best suited to the investigation, (5) the careful collection and critical evaluation of data bearing upon it, (6) the sound interpretation of data, . . . and (7) reaching the solution or conclusion to which the data most reasonably lead."

4. *Personal factors and scientific aptitude*

Scientific aptitude. Turning now from the thesis to the person who prepared it, the question arises concerning the nature of scientific aptitude. Among early scholars there was a firm belief that aptitude for science was aptitude for logic. This theory prevailed for over a dozen centuries, and even Roger Bacon, who was among the first to notice the sterility of formal logic, believed that there are two methods of acquiring knowledge: "through reasoning and through observation." He declared, however, "though reasoning may lead us to a conclusion or make us accept a conclusion, it does not remove our doubts so as to satisfy our mind with intuitive truth unless it finds it through experiment."[10] This position is not as sound as that of Francis Bacon, by whom the inductive method was described. He found, "the present system of logic rather

[8] Harold H. Bixler. *Check Lists for Educational Research,* p. 3.

[9] Fowler D. Brooks. "Criteria of Educational Research," pp. 724-25.

[10] Roger Bacon. *Opus Major,* vol. II, Pars Sexta, p. 167.

assists in confirming and rendering inveterate the errors founded on vulgar notions than in searching after truth, and is, therefore, more hurtful than useful." [11]

The issue was apparently not adjusted even in the nineteenth century, since John Stuart Mill deemed it necessary to state that "logic can never show that the fact A proves the fact B," or, as Herschel says: "A clever man, shut up alone and allowed unlimited time, might reason out for himself all the truths of mathematics, . . . but he could never tell by any effort of reasoning what would become of a lump of sugar if it were immersed in water." [12] Reaching the same conclusion, M. Berthelot said: [13] "C'est un des principes de la Science positive qu'aucune réalité ne peut être établie par le raisonnement." (It is one of the principles of positive science that no reality can be established by reasoning.)

In modern days there is no need for arguing that "science is not logic." Such knowledge does not give one the information needed to enable him to test himself and to develop himself in science. Turning to the definition of scientific ability, we find that Francis Bacon [14] describes it as love of truth, passion for research, power of suspended judgment, accuracy of statement, courage of steadfast endurance, accuracy of patient observation, and freedom from preconceived ideas.

Davy [15] gives very similar qualities. His list includes

[11] Francis Bacon. *Novum Organum*, p. 316.

[12] J. F. W. Herschel. *The Study of Natural Philosophy*, p. 36.

[13] M. Berthelot. *Science et Philosophie*, p. 10.

[14] *Op. cit.*, p. 317 ff.

[15] J. A. Paris. *Life of Sir Humphry Davy*, pp. 394–95.

patience, industry, and neatness in manipulation; accuracy and minuteness in observing, and registering the phenomena which occur; absence of preconceived notions; and an imagination active and brilliant in seeking analogies, yet entirely under the influence of the judgment in applying them. Last, he says, the memory must be extensive and profound.

Darwin is in substantial agreement with Bacon. In his *Life and Letters* he is quoted as saying:

> I think I am superior to the common run of men in *noticing things* which easily escape attention, and in *observing them* carefully. My *industry* has been nearly as great as it could have been in the observation and collection of facts.... My *love of natural sciences* has been steady and ardent.... I have steadily endeavored *to keep my mind free* so as to give up any hypothesis, however much beloved (and I cannot resist forming one on every subject) as soon as the facts are shown to be opposed to it.

Faraday's ideas are nearly identical with those given. As characteristics of scientific aptitude he gives judgment, lack of bias, wholesome self-abnegation, suspended judgment, clear and precise ideas, and a "certain amount" of imagination.

Helmholtz [16] believed mainly in "hard work," but he enumerates further the traits of orderliness, systematic labor, love of truth, patience, accuracy of results, appreciation of physical facts, and experimental bent, rather than a tendency to speculate. Jevons's [17] analysis includes impressionable mind, associating and identifying power, active imagination, vigorous powers of reasoning, candor and courage, industry, reservation of judgment, and "above all love of truth."

[16] H. von Helmholtz. *Popular Lectures of Scientific Subjects*, p. 6 ff.

[17] W. S. Jevons. *Principles of Science*, p. 574.

These views reveal clearly the opinion that scientific ability is a component of many factors. The opinion also is held that these factors vary in importance. To illustrate, if scientific aptitude consists of the six factors: originality, ability to formulate hypotheses, ability to generalize from data, accuracy and keenness in observation, persistence or sustained effort, and ability to discriminate between values, manifestly the factors are not of the same kind, and they are not of equal weight.

Keenness in observation is probably an inherent characteristic, dependent upon visual, tactile, and auditory acuity. If it is inherent, it probably cannot be much improved by training. Ability to generalize is partly a matter of general intelligence, and partly a matter of technique; it therefore can be improved. Patience or sustained effort is composed of habit and attitude; it can be acquired in a few days by a person of resolution. On the other hand, originality and creative imagination must be more complex, and are not to be changed in a brief period of time. A person lacking in these last two traits cannot be regarded seriously as a candidate for the doctorate.

Originality and scientific aptitude. In the most important study of scientific aptitude that has been made,[18] originality is omitted as an essential. The author holds, however, that total lack of imagination is normally impossible, for, quoting Ribot: "We are always inventing for an end, whether in the case of Napoleon imagining a campaign or a cook making up a new dish." He tries to show that in the case of all great discoveries in science, men did not speculate or im-

[18] D. L. Zyve. *An Experimental Study of Scientific Aptitude*, p. 27 ff.

agine, but they observed accurately and proceeded with the experiment with a keen sense of discrimination of value in segregating data, and forming plausible inductions and deductions. He agrees with Lord Kelvin [19] that "nearly all the grandest discoveries in science have been but the rewards of accurate measurement and patient, long-continued labor in the minute sifting of numerical facts."

Zyve believes, therefore, that if a man is thoroughly saturated with the subject-matter, and proceeds very carefully and painstakingly, after the scientific method, he has scientific aptitude. The inference is that most discoveries are by accident, since without imagination they cannot have been foreseen. College and university practice is not in accord with this notion. The regulations indicate a belief that much more than careful, plodding, painstaking, and conscientious collection of data is necessary to scientific discovery. Nevertheless, there is no difficulty in agreeing with Dr. Zyve that there is no abrupt break in the continuity of scientific aptitude. What the great scientist possesses to a large degree is possessed by the common man to an appreciable extent. Genius in science is not "a phenomenon beyond the domain of the laws of nature."

Views of noted scientists. Scientists as a rule testify to a faith in originality. Sir Humphry Davy considered the ability to formulate hypotheses as the most powerful instrument in scientific research. "Without hypotheses," he said, "there is no hope of discovery except by accident." "The illusions of the experimenter," said Pasteur, "are a part of his power; it is his preconceived idea that serves him

[19] J. A. Thomson. "Lord Kelvin," in *Introduction to Science.*

as a guide." Karl Pearson believes that "the disciplined imagination has been at the bottom of all great scientific discoveries."

Faraday's experience in liquefying chlorine is cited occasionally as an example of accidental discovery. He was, at the time, assistant to Sir Humphry Davy, who had set him at the task of heating chlorine hydrate in a closed tube. A visitor noticed an oily matter on the walls of the tube, and jokingly attributed it to Faraday's carelessness in using soiled apparatus. Faraday, somewhat surprised, having inspected the tube, "acknowledged the justice of the visitor's remark," in consequence of which he proceeded to file off the closed end of the tube. The result was an explosive evaporation of the oily substance.

Faraday, completely at a loss to explain the occurrence, repeated the experiment, and saw the liquid separate into two layers. He identified the oily matter in the lower layer, and, after a few tests, came to the conclusion that it gave off chlorine gas. The oily substance, therefore, was liquid chlorine. On examining this occurrence carefully it is found that the accidental circumstance consisted in the visitor's observing the oily matter, and in speaking to Faraday about it. There was nothing accidental about the heating of the chlorine hydrate in a closed tube; it is on this point that constructive imagination is revealed. Once Faraday seized the clue given him, his behavior was thoroughly scientific.

Improving originality. Whether or not originality can be acquired is a vital matter to science. A writer in the *Literary Digest* [20] believes so strongly. "Originality begets

[20] February 14, 1920

originality," he said, "one original mind inspires others to become more original, and not only inspires, but trains them to become inventive." An investigation of the originality of different peoples seems to substantiate this idea. France leads in originality in art, Germany in originality in physical science and music, the United States in invention.

This is due on the one hand to the influence of certain exceptional men, who have taught and inspired others to excel in the same lines of endeavor; on the other hand to education. No one can say, that although Russia has produced only one invention to 60,000 population, there are no brains in Russia with capacity for invention. If general and technical education have succeeded in making the French, English, Germans, and Americans 600 times as inventive as the Russians, this can mean only one thing — that originality and education go hand in hand. Originality can be learned.

Measurement of scientific aptitude. The writer believes there is a serious omission in the tests of scientific aptitude, to which we now turn, namely, the failure to take account of the creative imagination. One of the first attempts to measure scientific aptitude was made by M. Toulouse, who submitted Henri Poincaré to a series of psychological tests. The validity of the process is not known, but, since he reported his distinguished subject low in concentration, it has been assumed to be doubtful. The conclusions, however, pointed quite plainly to the intuitive character of ability in higher mathematics; a condition, which if true, seems to have little in common with inductive science.

Herring,[21] in 1918, prepared a test of scientific method. Eleven abilities, designated in the following way, comprised the test:

1. *Value.* The ability of the pupils to judge the relative values of different problems.
2. *Feasibility.* The ability to judge whether problems can or cannot be solved.
3. *Definition.* The ability to distinguish good definitions from bad.
4. *Clarity.* The ability to locate ambiguity.
5. *Statistics.* The ability to know when statistics are needed.
6. *Relevancy.* The ability to select facts that relate to problems.
7. *Recording.* The ability to select the best method of recording facts.
8. *Comparison.* The ability to distinguish good from bad comparisons.
9. *Classification.* The ability to recognize something foreign in a class.
10. *Arrangement.* The ability to arrange members of a class in useful sequence.
11. *Sufficiency.* The ability to judge whether the data are sufficient for the purpose.

Zyve [22] defines scientific aptitude in terms of ten traits, of which at least three: value, definition, and clarity are much like the traits given by Herring. The others are: suspended judgment *versus* snap judgment, experimental bent, detection of fallacies, ability to reason, accuracy of observation, ability to generalize, and caution.

Two forms of the test were given to graduate students engaged in research in physics, chemistry, and engineering. After the tests were scored, the subjects were rated by their

[21] J. H. Herring. "The Measurement of Some Abilities in Scientific Thinking," p. 540 ff.

[22] *Op. cit.*, pp. 26–27.

instructors in scientific aptitude. The average ranking of the judges was accepted as the final criterion. Correlations were then calculated between the ranks, as obtained from scores made on the tests, and the average of the ranks assigned by the judges. The resulting coefficients between test scores and rating of instructors were:

Chemistry	$.81 \pm .06$
Physics	$.93 \pm .04$
Engineering	$.98 \pm .008$

The reliability of the estimates of the judges was calculated in two ways: (1) by correlating the rankings given by a judge at the beginning of the experiment with the rankings given several months later, and (2) by correlating the estimates of one judge on the scientific aptitude of a subject with the estimates of the other judges. By the first plan, the coefficients of reliability range from $.77 \pm .09$ to $.96 \pm .01$; by the second plan they range from $.61 \pm .10$ to $.90 \pm .04$. The conclusion is that the estimates are reliable, and that the test really measures scientific aptitude.

Final conclusions. A writer [23] of to-day holds out hope of success in research to all who have the ability to graduate from a modern university when he says: "A man with a sufficient fund of knowledge and a close application to *one* art or science, will make good improvements in it, though his talents be not of the best; or, in other words, though he be not a great genius."

Jackson [24] continues:

Conquering the unknown in the field of knowledge is somewhat

[23] C. M. Jackson. "Obstacles to Research," p. 820.

[24] *Ibid.*, p. 822.

like civilization invading a new territory. A few bold and talented explorers may lead the way and blaze out new paths in the wilderness; but their excursions would be fruitless unless followed up by pioneer settlers, who by arduous labor develop the country and render its resources available for mankind. Moreover, even the explorer is in many ways largely dependent upon the knowledge and equipment furnished by others, his predecessors and his supporters.

Investigation doubtless lags more frequently from lack of sustained interest than from any other cause. "Appreciation by one's fellows is a most powerful stimulus. Thus a general recognition of good research work will greatly encourage the worker to persist in spite of all obstacles."

In conclusion, the preparation of a thesis carries with it more than the reward of an academic degree. It serves as an introduction into the fraternity and fellowship of a large body of devoted seekers after truth; it opens the door to the happiest kind of immortality. The number of interesting and worth-while studies to be made is practically endless. New discoveries, and the ideas and possibilities suggested by them, have in recent decades awakened an enthusiasm for knowledge akin to that produced by the Renaissance. "There never were any signs of an approach to finality in science." Science is fostering a progress that may be measured, not in mere billions of dollars, but in the finer though less tangible terms of appreciation, sacrifice, service, and truth.

QUESTIONS AND EXERCISES

1. Find who passes judgment upon a thesis in your institution. Does he give a grade upon it? If so, how is the mark or grade arrived at?

2. Using the rating sheet included in this chapter, or one of your own devising, grade a thesis and check it as acceptable or non-acceptable. What advice would you give for its improvement?
3. Define originality, and show how it is related to creative imagination.
4. Make up a list of from five to ten individuals you know who, in your opinion, bear evidence of possessing originality. Explain why you distinguish each by originality.
5. In what way did Francis Bacon display originality? Darwin? Newton? Agassiz? Jenner?
6. Give reasons why a student should be expected to indicate other studies which may grow out of the field in which he has conducted his research.
7. Give some evidence that truth can never result from logic.
8. Read the biography of a great scientist, and enumerate as many personal qualities related to his success in science as you can.
9. Show that judging a thesis is an example of normative science, if the evaluation is dependable.
10. Give some proof that university authorities apparently believe that originality is a necessary constituent of scientific method.
11. Compare the method of measuring scientific method devised by Herring, with the method devised by Zyve. Which is superior? Why?
12. What characteristics of the scientist would you take greatest pride in possessing? Are these characteristics innate, or due to training? Of what significance is this distinction? Discuss.

PROBLEM 20

Checking a Thesis

Situation 20: At the University of Carizona, a uniform device for checking theses has been devised. It takes account of: (*a*) problem, (*b*) method, (*c*) reliability, (*d*) validity, (*e*) arrangement, (*f*) and (*g*) bibliography.

Although the checking list is presumed to be valuable to a member of the faculty who is judging a thesis, its chief purpose is

for the use of the students, affording a standard to help them in planning and judging their own work. They need a little practice in the use of the device, not only in getting ready to prepare their own theses, but in obtaining training for judging the theses of others when they in turn become university teachers and directors of research.

Problem 20: Select a thesis that belongs in the field in which you propose to write, and apply to it the checking schedule given in the text, or one of your own devising.

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